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# Evaluation of Back Flow Prevention Devices: A State-of-the-Art Report

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Prepared for

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Grover C. Sherlin
Robert W. Beausoliel

Center for Building Technology
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

June 1976

Final Report

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A significant potential for potable water supply contamination exists within all water supply systems due to backflow and cross connections. Surveillance of the water supplies to protect from such hazards requires continuing vigilance by the administrators of cross-connection control programs, and continuing upgrading of technical criteria and methods of evaluation.

The Environmental Protection Agency assists local (usually municipal) authorities, through the State water supply agency, in establishing and operating cross-connection control programs. Essential to these programs are (1) information on the suitability of commercially available devices for use in potentially high-hazard locations, and (2) practical and effective standardized test methods for evaluation of devices. The National Bureau of Standards investigation reported herein addresses the two needs identified.

This study includes a systematic review of the literature, together with consultations and visits with water purveyors, plumbing officials, laboratory officials and researchers in this field. Emphasis has been placed on those devices, test methods, and laboratory practices considered most essential to an effective assessment of the state-of-the-art. Also, test development needs were identified in a few areas of greatest concern.

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**Edward O. Vetter,** ***Under Secretary***
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**NATIONAL BUREAU OF STANDARDS, Ernest Ambler,** ***Acting Director***

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# EVALUATION OF BACKFLOW PREVENTION DEVICES:

# A STATE-OF-THE-ART REPORT

by

Grover C. Sherlin and Robert W. Beausoliel

## ABSTRACT

A significant potential for potable water supply contamination exists within all water supply systems due to backflow and cross-connections. Surveillance of the water supplies to protect from such hazards requires continuing vigilance by the administrators of cross-connection control programs, and continuing upgrading of technical criteria and methods of evaluation.

The Environmental Protection Agency assists local (usually municipal) authorities, through the State water supply agency, in establishing and operating cross-connection control programs. Essential to these programs are (1) information on the suitability of commercially available devices for use in potentially high-hazard locations, and (2) practical and effective standardized test methods for evaluation of devices. The National Bureau of Standards investigation reported herein addresses the two needs identified.

This study includes a systematic review of the literature, together with consultations and visits with water purveyors, plumbing officials, laboratory officials and researchers in this field. Emphasis has been placed on those devices, test methods, and laboratory practices considered most essential to an effective assessment of the state-of-the-art. Also, test development needs were identified in a few areas of greatest concern.

Key Words: Backflow; backflow preventers; back pressure; back-siphonage; cross-connections; health hazard; potable water; vacuum breaker; water supply.

# 1. INTRODUCTION

## 1.1 Purpose and Scope

As approved Dec. 16, 1974, Public Law 93-523 (called the "Safe Drinking Water Act") marks the first time a national commitment has been made to safeguard public drinking water supplies. It provides that the Federal Government - U.S. Environmental Protection Agency (EPA) - set national standards, and that the states enforce those standards and otherwise supervise public water supply systems and sources of drinking water. The Act gives EPA responsibility for setting minimum national drinking water standards for all public water systems throughout the United States having at least 15 service connections or regularly serving at least 25 people. EPA is also authorized to help States improve their drinking water programs by providing technical assistance, employee training and financial support.

Although the Safe Drinking Water Act is primarily concerned with the contaminants [1] that must be processed out of the raw water by those persons who own and operate a public water supply system, EPA has long been concerned with contaminants that may enter a potable water system by backflow from a consumer's pipeline through a cross-connection.

In this particular concern, EPA assists local (usually municipal) authorities, through the State water supply agency, in establishing and operating cross-connection control programs. Essential to these programs are (1) up-to-date information on the suitability of various types of commercially available protective devices for use in potentially high-hazard locations, and (2) practical and effective standardized test methods for use in evaluating such devices. The collective experience of EPA, other federal agencies, and state agencies has shown that a significant potential for potable water supply contamination exists within all water supply systems, and that minimization of such hazards requires continuing vigilance by the administrators of cross-connection control programs, and continuing upgrading of the state-of-the-art in matters of technical criteria and methods of evaluation. EPA has requested the National Bureau of Standards (NBS) to provide assistance in meeting the needs identified above.

NBS has undertaken to perform the tasks of (1) producing a state-of-the-art survey and report, drawing upon available NBS laboratory findings to evaluate existing or modified test procedures, and (2) of developing guide criteria for the laboratory evaluation of backflow protection devices and examining protocols required for evaluation purposes.

This report assesses the state-of-the-art for the evaluation of devices used to protect potable water supplies against backflow contamination. Backflow contamination of a water supply can arise in either of two plumbing system configurations. In the first configuration, a so-called "direct cross-connection" exists where the potable water supply piping is mechanically joined to piping or pressurized devices which may contain potential contaminants. Examples of direct cross-connections are inter-connections between dual-purpose water distributing systems (potable system and a protection system, laboratory water system, etc); completely submerged inlets from water supply lines to closed plumbing fixtures, tanks or vats; and continuous water connections between supply and drain systems, pump priming lines, etc.

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[1] A number of terms and abbreviations have been defined in section 7.

In the second configuration, an "indirect cross-connection" or a "potential cross-connection" exists. This is one in which the inter-connection is not continuous and the completion of the cross-connection depends upon certain possible occurrences. Examples: water closets with direct flush valve supply, bathtubs or lavatories with faucet openings that may become submerged, etc. [1, 2], [2]

In either case, i.e., direct or indirect cross-connection, backflow results from an adverse pressure differential across the cross-connection. Thus, the necessary conditions for potable water contamination by backflow are the simultaneous occurrence of events which produce (a) a cross-connection, (b) an adverse pressure differential across the connection, and (c) the presence of a contaminant on the normal downstream side of the cross-connection. If prevention of conditions (b) and (c) above could be assured, special backflow prevention devices would not be necessary. However, many of the types of events which give rise to either the presence of a contaminant or an adverse pressure differential or both appear unexpectedly beyond human control; therefore, there are many design situations where adequate backflow protection devices must be used.

This study has involved collection of information from a number of sources. These include a systematic review of the literature, together with consultations and visits with water purveyors, plumbing officials, laboratory officials and researchers in this field. To the extent that the scope of these investigations was restricted by the resources available for this study, emphasis has been placed on those devices, test methods, and laboratory practices considered most essential to an effective assessment of the state-of-the-art. Also, test development needs were identified in a few areas of greatest concern.

## 1.2 Fundamentals of Backflow

Backflow can result when either a direct or an indirect cross-connection to a potable water supply experiences an adverse pressure differential. In other words, backflow can occur when the pressure in the potable water system is, or momentarily becomes, less than that in the system to which it is connected. For example, consider the hypothetical and typical illustration of a backflow situation depicted on figure 1. Here an upfeed water supply riser serves a number of fixtures in a tall building. Assuming that all fixtures are closed and the line supplying water to the building is broken in the street, the column of water in the riser will fall to a level of approximately 33 feet to balance the atmospheric pressure on the broken end of the pipe thus creating a vacuum in the upper levels of the riser. Then if, as shown on this figure, the water supply faucet of fixture "A" (with hose submerged in laboratory sink) were opened, the contents of the sink would, under the atmospheric pressure, be "sucked" or back-siphoned into the riser. This volume of non-potable liquid would be distributed to other water outlets in the building after the water service was restored; consequently, a health hazard for occupants of the building served by that riser would result. It is conceivable that this slug of non-potable liquid could travel through the riser and the service piping to the street main where it would subsequently be transferred to the service piping of other premises and thereby create a widespread health hazard.

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[2] Numbers in brackets refer to sequential listing of references in section 8.

Dawson and Kalinske have demonstrated that a column of water in a closed riser as shown in figure 1 would fall to its final position shown in about seven seconds [3]. The falling column of water would first accelerate, then decelerate to zero velocity at the 33-foot level shown. Therefore, it is seen that the potential back-siphonage hazard can occur quite rapidly. It is interesting to note that a subatmospheric condition would exist temporarily inside the riser as the water column fell even if the riser were completely open at the top. This condition would occur because the atmospheric air flowing into the riser would experience a loss of pressure due to the entrance loss (frictional loss) and also a loss of pressure in the direction of flow due to pipe friction and velocity head. Therefore, even if means were developed to completely vent a riser, some degree of back-siphonage potential would exist during the transient period when the water column was falling. Of course, if the riser were vented, all of the water in the riser would flow into the excavation shown and no potential back-siphonage hazard would exist after flow ceased.

If, as indicated by figure 1, a faucet "B" were open at the instant the water main were broken, air would immediately begin entering the riser as the water fell from the riser. This, of course, would greatly reduce the peak magnitude of the vacuum in the riser as well as its duration. Assuming that the volume of vacuum was initially about 7 1/3 gallons (internal volume of the pipe), the method of Dawson and Kalinske [3] indicated that the time to dissipate the vacuum from 29 inches of mercury to atmospheric pressure would be 4.6 seconds through a 3/8-inch diameter opening at the faucet. See Appendix Section 10.1 for details concerning the sample calculation and applicable equation.

Referring again to figure 1, we may assume that faucets "A" and "B" were closed and the interconnection "C", a check valve between the heating system and the water system, was leaking. Then chemically treated heating

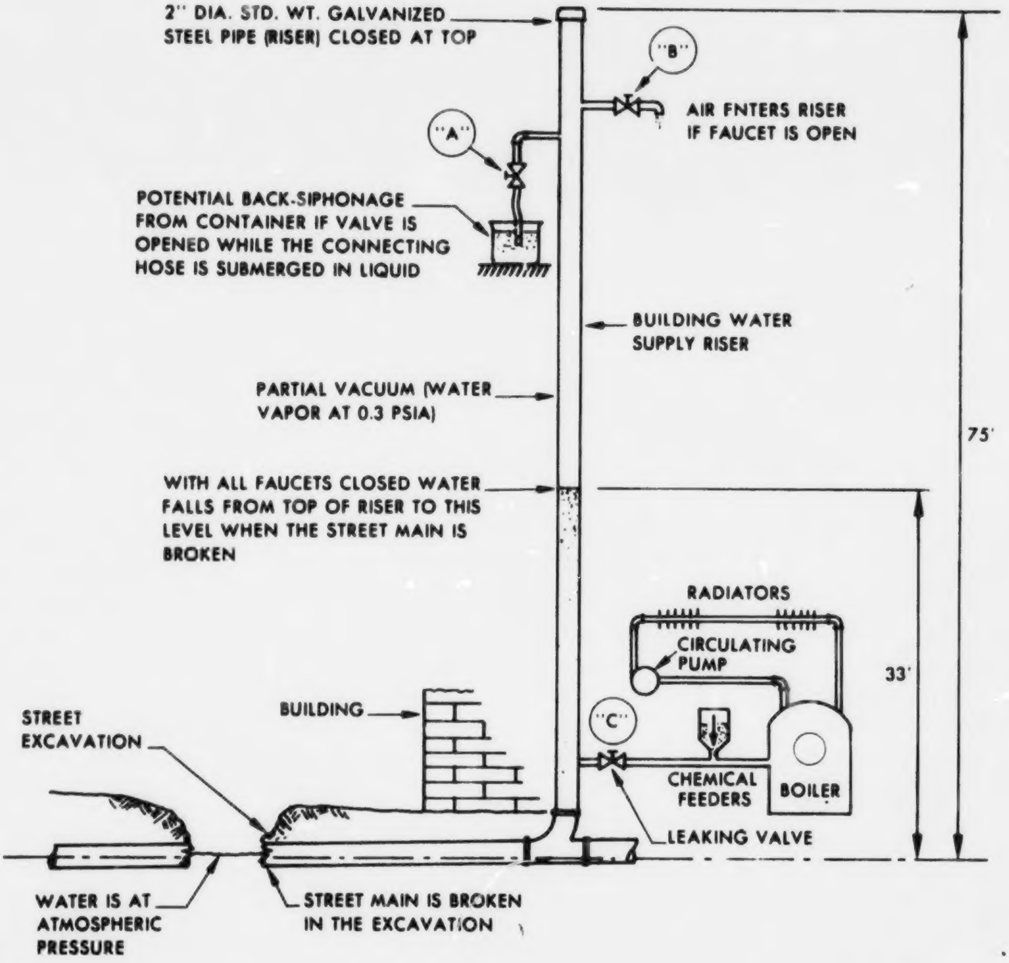
2" DIA. STD. WT. GALVANIZED STEEL PIPE (RISER) CLOSED AT TOP
"B"
AIR FNTERS RISER IF FAUCET IS OPEN
"A"
POTENTIAL BACK-SIPHONAGE FROM CONTAINER IF VALVE IS OPENED WHILE THE CONNECTING HOSE IS SUBMERGED IN LIQUID
BUILDING WATER SUPPLY RISER
PARTIAL VACUUM (WATER VAPOR AT 0.3 PSIA)
75'
WITH ALL FAUCETS CLOSED WATER FALLS FROM TOP OF RISER TO THIS LEVEL WHEN THE STREET MAIN IS BROKEN
RADIATORS
CIRCULATING PUMP
33'
BUILDING
STREET EXCAVATION
"C"
CHEMICAL FEEDERS
BOILER
LEAKING VALVE
WATER IS AT ATMOSPHERIC PRESSURE
STREET MAIN IS BROKEN IN THE EXCAVATION

Figure 1. Illustrating Two Examples of Backflow: (A) by Backsiphonage and (C) by Back Pressure

system water would backflow into the riser from the back pressure caused by the circulating pump and/or boiler. When the break in the street main was subsequently repaired and service restored, the slug of chemically treated water could be distributed through all potable water outlets within the riser and perhaps to other premises connected to the street main.

There are, of course, many other more common situations which can give rise to adverse pressure differentials of the types shown on figure 1. For example, back-siphonage in cross-connections can occur by way of a vacuum generated in the potable water piping of any building as follows:

a. Draining of hot water heaters and/or a water supply system without venting air into the system can create vacuums within the system.

b. "Imperfections of workmanship at tee connections or couplings may produce restrictions which would cause high water velocities with consequent reduction in pressure. The pressure may be reduced sufficiently so as to produce a negative pressure at the side outlet of the tee and consequent siphonage from the submerged inlet fixture to which the side of the tee is connected." [3] Excessive water demand can result in equally high velocities in the main line and excessive reduction in pressure in branch piping with similar back-siphonage.

This section has indicated that the possibility of backflow depends on a number of factors usually unique to a particular cross-connection situation. Unfortunately, very little data are known to exist on the frequency-of-occurrence of adverse pressure differentials, contaminant presence, or both, with or without backflow prevention devices installed. Therefore, no means exist presently to predict backflow hazard potential or hazard reduction through use of backflow prevention devices. If such data were available, analyses of this type would be straightforward and quite useful not only in identifying high risk cross-connection situations, but also in predicting the relative effectiveness of alternative methods of backflow protection.

# 2. BACKGROUND INFORMATION

## 2.1 Historical Background and Recorded Incidents of Backflow Through Backflow Connections and Cross-Connections

The previous section has given an overview of the mechanisms of the cross-connection problem. This section presents some actual backflow incidents chronologically and gives indication of what is being done presently to prevent such incidents.

A highly publicized and investigated incident involving backflow resulted in an outbreak of amoebic dysentery in a hotel during the World's Fair in Chicago in 1933. This epidemic brought world-wide attention to Chicago and stands as a landmark in the development of cross-connection control efforts. The most important outcome from the Chicago incident was the recommendation that air-gap separation be used for preventing contamination of the potable water supply [4]. Vacuum breakers were not available during the Chicago epidemic era, but by 1945 vacuum breakers had been developed and approved for use [4].

"Craun and McCabe [5] conducted a review of the causes of water borne-disease outbreaks occurring in the U.S. during 1946-70. During this 25 year period, there were 358 recognized outbreaks of disease or chemical poisoning attributed to contaminated drinking water. These outbreaks affected 72,358 individuals and resulted in 36 deaths....

The majority of the outbreaks (71 percent) resulted from contamination of private, individual water systems; but most of the illnesses (83 percent) occurrred as the result of outbreaks in community water systems. The major cause of outbreaks in community water systems was contamination of the distribution system, primarily through cross-connections and back siphonage; however, few illnesses resulted from this source because the contamination was confined to rather small areas." [6] Table 1 lists some of the more sensational, recently recorded, incidents of backflow.

The U.S. Environmental Protection Agency publication, "Cross-Connection Control Manual," cites a number of interesting incidents including the following concerning the sill faucet or hose bibb [7].

> "A California laborer had been using an aspirator, attached to a garden hose, to spray a driveway with weed killer containing arsenic. Sometime while he was at the job, the water pressure reversed. Taking no notice of the incident, the man disconnected the hose and, feeling thirsty, drank from the bibb of the hose connection at the house. Arsenic in the waterline killed him."

TABLE 1. RELATIVELY SENSATIONAL INCIDENTS OF BACKFLOW

| INCIDENT LOCATION | TYPE OF BACKFLOW CONNECTION OR CROSS-CONNECTION | CAUSE | RESULT OF CONNECTION |
|---|---|---|---|
| Michigan Hospital - 1964 | Between an autopsy table & water supply line to a drinking fountain | Back siphonage | Nurses had noticed rusty water (blood) at the fountain for some time |
| Holy Cross Varsity Football Team - 1969 | Between a submerged outlet in the irrigation system and potable water line serving the irrigation system & team | Back siphonage | Most team members suffered infectious hepatitis |
| Fulton National Bank, Atlanta, Georgia - January 1970 | Between the potable supply & the air conditioning chilled water system | Probable back siphonage | Yellow water noticed at drinking fountains |
| Homes in Silverton, Ohio,Suburb of Cincinnati,1969 | Between wine cask or barrel & potable water supply in nearby winery - | Back siphonage | A hose supplying potable water for cask washing had its outlet submerged in wine. Wine back-flowed from the cask and flowed from the faucets in the homes. |
| A home in Renton, Washington 1956 | Between a large quantity of gasoline & the potable water supply | Back pressure | Flash fire occurred at a water faucet within the home. |
| Ontario, California sewage treatment plant - 1968 | Cross-connection on premises, but the public supply was protected by a backflow preventer in the service line to the premise. | Back pressure and/or back siphonage | Backflow preventer protected the municipal supply by containing the contaminant within the premise but did not protect employees who suffered from a water borne disease. |
| An auditorium in Boston, Mass. June, 1974 | A faulty valve allowed a yellow chromate rust inhibitor in the air conditioning system to back into the drinking water supply | Back pressure or back siphonage | At least two of 3000 diners at a banquet noticed a yellowish hue in the water. Analysis of water by an instrument exhibitor established presence of toxic chromium. |

Hutchinson, speaking to the American Water Works Association [8] and earlier to the American Society of Sanitary Engineering [9], stated that there is no organized cross-connection incident reporting system. It is conceivable that if some mechanism for reporting such incidents existed, it would be found that the number of backflow and cross-connection incidents is actually many times larger than current knowledge indicates. If practical, a reporting system would be invaluable in setting priorities for device usage and for pinpointing and correcting causes. Such a system might include records of low water pressure and vacuum in the water piping to hazardous premises such as sewage treatment plants and industrial plants. Recurring low pressure would indicate system deficiencies requiring correction.

During a cross-connection survey in Calhoun County, Michigan, [10] pressure-vacuum recording gages were installed in some 45 different locations. A total of ninety (90) charts were obtained during the survey and sixteen of these showed low or negative pressure. The existence of low pressure in the potable water supply indicates potential for backflow.

## 2.2 Navy Study of FCCCR Certification Procedures

During World II,according to Navy Technical Note N-1169 [11] there were numerous backflow occurrences caused by docked Naval and and merchant vessels accidentally pumping harbor water through on-shore water lines. Sanitary protection of the water supply was frequently neglected due to the urgency of wartime schedules. As a result,a group of individuals concerned with backflow prevention proposed in 1944 to establish a foundation 3/ at the University of Southern California to study the problem. On 14 September 1944, the Board of Trustees of the University established the FCCCR as a formal arm of the University.

The FCCCR adopted definitions and specifications for backflow prevention devices as early as 1948 when Paper Number 5 [12] was published. In 1959, an expanded set of definitions and specifications was published as USCEC Report 48-101. [13] Shortly thereafter, a joint committee representing numerous Southern California water utilities expanded USCEC Report 48-101 into what became known as the Manual for Cross-Connection Control - Recommended Practice.[14] This manual,which contains additional information on the application of backflow preventers, was first published in 1960. The 2nd and 3rd Editions were published in 1965 and 1966,respectively, with minor revisions. During 1967 and 1968, the manual (particularly Section 10 covering specifications) was thoroughly reviewed by a committee representing water utilities, local health authorities, manufacturers, and the Foundation.

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3/ At the time of the Navy report the name was Foundation for Cross-Connection Control Research (FCCCR).

The major changes which resulted were incorporated in the 4th Edition of the Manual,[15] published in 1969.

Navy Technical Note N-1169 [11] resulted from the need to understand better the impact of a change in certification procedure by FCCCR. The Naval Civil Engineering Laboratory at Port Hueneme, California conducted a survey of authorities concerned with backflow prevention, including persons in city, county,state and federal governments. Responses from 62 localities are summarized in Table 2. The column headings in the table are of necessity cryptic, but by following the arrangement of the survey questions (reproduced here as Appendix 10.2) possible confusion of meanings is minimized. Nearly half of those responding indicated that the reduced pressure principle backflow preventer was the minimum protection required for a health hazard to the potable water supply. Although the Navy has relied heavily on certification procedures to assure that the very best protection would be provided at its bases and docks, it may find that periodic field testing of devices is more certain assurance of best protection.

## 2.3 The A.S.S.E. Concern for Backflow Problems

The American Society of Sanitary Engineering (A.S.S.E.) was founded in Washington D.C. in 1906, eight years prior to the advent of the first U.S.PHS standards for drinking water. Although the membership of the society for many years was small, the yearbooks indicate that active members concerned themselves with many aspects of water supply and waste disposal with primary concern for public health.

In the NBS file is a collection of three papers prepared by William C. Groeniger, [16, 17, 18] who in the early thirties was for several years Chairman of the Research Committee of A.S.S.E., and earlier an Ohio State inspector of plumbing. He and the Research Committee pioneered activities toward solution of cross-connection problems. In 1932, Major Groeniger, in the capacity of Chairman of the Research Committee, served as Chairman of an A.S.S.E. conference on "Cross Connections" [19] held at NBS on February 24 and 25. The conference registration list of 54 included a broad sampling of concerned persons: physicists, engineers, plumbing contractors, plumbing component manufacturers, and public health officials. Of particular interest was the presence of H. H. Matthieson, Chief Sanitary Engineer of the Los Angeles Health Department because other authors have indicated that Los Angeles was early the center of activity in testing and evaluating mechanical backflow preventers -- as early as 1934.

The first national standards for devices to prevent or to control backflow (ASA A40.4 - 1942 "Air Gaps" and ASA - A40.6 - 1943 "Backflow Preventers in Plumbing Systems" were published by the American Standards Association (ASA). A.S.S.E. did not have representatives on the A40 committee of ASA but became a sponsor with the American Society of Mechanical Engineers (ASME) when part of A40 was changed to A112, Committee on Standardization of Plumbing Material and Equipment, in 1958.

Table 2. Results of a Survey Made by the Naval Civil Engineering Laboratory and Reported in Navy Technical Note N 1169

**ABBREVIATIONS:**

RP = Reduced pressure zone backflow preventer
DCV = Double check valve assembly
C = The water user or customer
U = The utility supplying water
L = An agency, test lab or person certified by the Utility
A = As required

| | 1. Type of Agency: | | | 2. Minimum Protection Required for Health Hazard: | | | | | 3. Certification or approval required for devices: | | | | 4. Will new FCCR 1-yr.test program be accepted? | | 5. If cert. not renewed, exist. devices will be: | | 6. Purchase & install. costs borne by: | | 7. Make of RP Device installed: | | | | 8. Inspect.,Test and Maint. Policy: | | | | | | | | | 9. Failures and problems experienced with devices: RP | | | | DCV | 10. Other Comments | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | City, County or Port Auth. | State | Federal | Air Gap | R.P. Device | DCV Assembly | Other Protection | No Protection Specified | Full Approval by FCCCR | Provis. Approv. by FCCCR | Other Approval | None Required | Yes | No | Replaced ASAP | Accepted as Orig. Approv. | Water Utility | Customer | BEECO | CRANE | CLA-VAL | Other | Freq. of Inspections (mo.) | Freq. of Tests (mo.) | Freq. of Maint. (mo.) | Inspection Performed by | Test Performed by | Maint. Performed by | Inspection Paid by | Test Paid by | Maint. Paid by | BEECO | CRANE | CLA-VAL | OTHER | | Freeze Protection | Policy Change in Future |
| 62 AGENCIES SURVEYED - Total | 55 | 5 | 3 | 9 | 29 | 14 | 5 | 4 | 9 | 7 | 19 | 7 | 15 | 0 | 0 | 13 | 0 | 27 | 28 | 14 | 15 | 1 | | | | | | | | | | 3 | 1 | 7 | 1 | 15 | 22 | 5 |
| 1. Alabama State Docks | x | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2. Baltimore, Md. | x | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | |
| 3. California | | x | | | | x | | | | | x | | | | | | | | | | | | 12 | 12 | A | | | C | | | C | | | | | | | |
| 4. Charleston, S.D. | x | | | | x | | | | | | x | | | | | | | x | x | | x | | 6 | A | A | U | U | C | U | U | C | | | | | x | x | |
| 5. Chicago, Ill. | x | | | x | | | | | | | x | | | | | | | x | x | | x | | A | A | A | U | U | | U | | | x | | x | | x | x | x |
| 6. Cleveland, Ohio | x | | | | | | x | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| 7. Corpus Christi, Texas | x | | | | | x | | | | | | | | | | | | | | | | | 6 | 6 | A | U | U | U | | | | | | | | | | |
| 8. Dallas, Texas | x | | | | x | | | | | | x | | | | | x | | x | x | | x | | 12 | 12 | A | U | U | C | U | U | C | | | | | x | x | |
| 9. Denver, Colo. | x | | | | x | | | | x | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10. Detroit, Mich. | x | | | | x | | | | | x | | | x | | | x | | x | x | x | x | | 24 | A | A | U | U | | U | U | | | | | | x | x | |
| 11. Duluth, Minn. | x | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12. Duluth, Seaway Port | x | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | |
| 13. Galveston, Texas | x | | | | x | | | | | | x | | | | | | | | x | | | | 12 | | | | | | | | | | | | | | | |
| 14. Hawaii State Harbors | x | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15. HEW Inter. Carrier Br. | | | x | | | | x | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16. HEW Nat. Inst. of Health | | | x | | x | | | | x | | | | x | | | | | | x | x | x | | 12 | 12 | 36 | C | C | C | C | C | C | x | x | x | | x | | |
| 17. Honolulu, Hawaii | x | | | | x | | | | x | | | | x | | | x | | x | x | x | x | | 12 | 12 | 60 | L | L | C | C | C | | | | x | | | | |
| 18. Houston, Texas | x | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19. Houston, Port Nav. Dist. | x | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20. Indianapolis, Ind. | x | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21. Jacksonville, Fla. | x | | | | | | | x | | | | x | | | | | | | x | | x | | | | | | | | | | | | | | | | | |
| 22. Jersey City, N.J. | x | | | | x | | | | | | x | | | | | | | | | | | | 12 | 12 | A | | | | | | | | | | | | x | |
| 23. Long Beach, Calif. | x | | | | x | | | | | x | | | x | | | x | | x | x | x | x | | 12 | 12 | A | L | L | L | C | C | C | | | x | | x | | |
| 24. Los Angeles, Calif. | x | | | | x | | | | | x | | | x | | | x | | x | x | x | x | | 12 | 12 | A | L | L | C | C | C | C | | | x | | x | | |
| 25. Louisville, Ky. | x | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26. Maryland Port Authority | x | | | | | x | | | | | | | | | | | | | | | | | 24 | | | | | | | | | | | | | | x | |
| 27. Massachusetts Port. Auth. | x | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28. Minneapolis, Minn. | x | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29. Milwaukee, Wisc. | x | | | x | | | | | | | | | | | | | | | | | x | x | | | | | | | | | | | | x | | | x | |
| 30. Mobile, Ala. | x | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31. New Orleans, La. | x | | | | x | | | | | x | | | x | | | x | | x | x | x | | | 6 | 6 | A | U | U | C | C | C | C | | | x | | | | |
| 32. New Orleans Port Board | x | | | | x | | | | | x | | | x | | | x | | x | x | x | x | | 6 | 6 | | | | | | | | | | | | | | |
| 33. New York Port Authority | x | | | | | x | | | | | x | | | | | | | | | | | | 12 | | | | | | | | | | | | | | x | |
| 34. Newport News, Va. | x | | | | | | | x | | | | | | | | | | x | x | | | | | | | | | | | | | | | | | | | |
| 35. Norfolk, Va. | x | | | | | x | | | | | | x | | | | | | x | x | x | | | A | A | A | U | U | | | | | | | | | x | x | |
| 36. Oak Ridge Nat'l Lab. | | | x | | x | | | | | | x | | | | | | | x | x | x | | | 12 | 12 | | C | | | | | | | | | | | x | |
| 37. Oakland, Richmond, Calif. | x | | | | | x | | | | | | x | | | | | | x | x | x | | | 12 | 12 | A | U | C | C | U | C | C | | | x | | x | | |
| 38. Ohio State Dept. Health | x | x | | | x | | | | x | | | | x | | | x | | x | x | | x | | 12 | 12 | | | | | | | | | | | | | x | |
| 39. Oregon | | x | | | x | | | | x | | | | | | | | | | | | | | 12 | 12 | A | L | L | | C | C | C | | | | | | | |
| 40. Philadelphia, Pa. | x | | | | | x | | | | | x | | | | | | | x | x | | | | | | | | | | | | | | | | | x | x | |
| 41. Phoenix, Ariz. | x | | | | x | | | | | | x | | | | | | | x | | | | | 1 | A | A | U | U | U | U | | | | | | | | | |
| 42. Portland, Ore. | x | | | | x | | | | x | | | | | | | | | x | x | | | | 12 | 12 | A | U | U | U | C | C | C | | | | | | x | |
| 43. Providence, R.I. | x | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 44. Richmond, Va. | x | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 45. Sacramento, Calif. | x | | | | x | | | | | | | x | | | | | | | x | | | | | | | | | | | | | | | | | x | | |
| 46. St. Louis, Mo. | x | | | | x | | | | x | | | | x | | | x | | x | x | | | | 24 | 24 | A | L | L | C | C | C | C | | | | | | x | |
| 47. St. Paul, Minn. | x | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 48. San Diego, Calif. | x | | | | x | | | | | x | | | x | | | x | | x | x | x | x | | 6 | 6 | 6 | U | U | U | U | U | U | | | | | x | | |
| 49. San Jose, Calif. | x | | | | x | | | | x | | | | x | | | x | | x | x | | | | 12 | 12 | A | L | L | L | C | C | C | x | | | | | | |
| 50. San Jose Water Works | x | | | | | x | | | | | | x | | | | | | x | | | | | | | | | | | | | | | | | | | | |
| 51. San Francisco, Calif. | x | | | | x | | | | | | | x | | | | | | x | x | x | | | 12 | 12 | A | U | U | C | U | U | C | | | | | x | | |
| 52. Savannah, Ga. | x | | | | x | | | | | | x | | | | | | | x | | | | | 6 | | | | | | | | | | | | | | | |
| 53. Seattle, Wash. | x | | | | x | | | | | | x | | x | | | x | | x | x | | x | | 12 | 12 | A | L | L | L | U | U | C | | | | | x | x | x |
| 54. Seattle, Port of | x | | | | | x | | | | | x | | | | | | | | x | | | | | | | | | | | | | | | | | | x | |
| 55. So. Carolina | | x | | | x | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 56. S. Carolina St. Port | x | | | | | | x | | | | | x | | | | | | | | x | | | | | | | | | | | | | | | | | | |
| 57. Tacoma, Wash. | x | | | | x | | | | x | | | | x | | | x | | x | x | x | x | | 12 | 12 | A | U | U | C | U | U | C | | | | | | x | x |
| 58. Tampa, Fl | x | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 59. Virginia St. Ports Auth. | x | | | | x | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | x | |
| 60. Washington, D.C. | x | | | | x | | | | | | x | | | | | | | | x | | | | | | | | | | | | | | | | | | x | |
| 61. Washington State | | x | | | x | | | | | x | | | x | | | | | x | | | | | 13 | | | | | | | | | | | | | | | x |
| 62. Wilmington, Del. | x | | | | | | | | | | | | | | | | | x | | | | | 3 | 3 | | U | U | | C | C | | | | | | | x | |

The first output of the A.S.S.E. Standards Committee on May 1966, A.S.S.E. 1001, "Pipe Applied Atmospheric Type Vacuum Breakers," received approval of the American National Standards Institute [4] A112 Committee to become ANSI A112.1.1 - 1971. [20]

The A.S.S.E. 1002 covering standards and tests procedures for water closet flush tank anti-siphon ball cocks was issued in October 1964 and revised in 1968 but has not yet met the approval of ANSI.

More recently the Standards Committee has focused its attention on five additional standards for backflow preventers and has published them as A.S.S.E. 1011, 1012, 1013, 1015, and 1020 [21, 22, 23, 24, 25]. All of these are now being considered by the ANSI A112 Committee for adoption.

Backflow preventers include devices and arrangements such as the air gap, the barometric loop, double check valve assemblies, reduced pressure zone back pressure backflow preventers, and vacuum breakers. Each of these types will be described and categorized.

## 2.4 Backflow Prevention Devices and Piping Arrangements

Figure 2 shows two applications of an air gap whereby protection against back siphonage can be assured as long as there is no tampering with the gap. For example it is quite possible to slip a short length of rubber tubing or rubber hose into the faucet of the lavatory, or sink without anticipating the hazards. The hose could lie in the stopped sink filled to the overflow outlet with contaminated wash water, and the faucet could be partially opened to supply water for a continuously flowing wash operation. Should a sudden vacuum occur on the water supply line contaminated wash water would back-siphon out of the sink into the potable system.

When water is needed to be under pressure for a particular application water is delivered to a tank through an air gap as illustrated in Figure 2 and a booster pump, located between the tank and point of use, can provide the necessary pressure. However, when the booster pump fails to operate and repair or replacement is not immediately possible, maintenance men have piped across the air gap to make use of the pressure in the potable supply line. Such an action could be more hazardous to human life than the act of putting a copper penny behind a blown electrical fuse.

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[4] Founded in 1918 as the American Engineering Standards Committee, it became the American Standards Association (ASA) in 1928, the United States of America Standards Institute (USASI) in 1966 and now American National Standards Institute (ANSI) since October 1969.

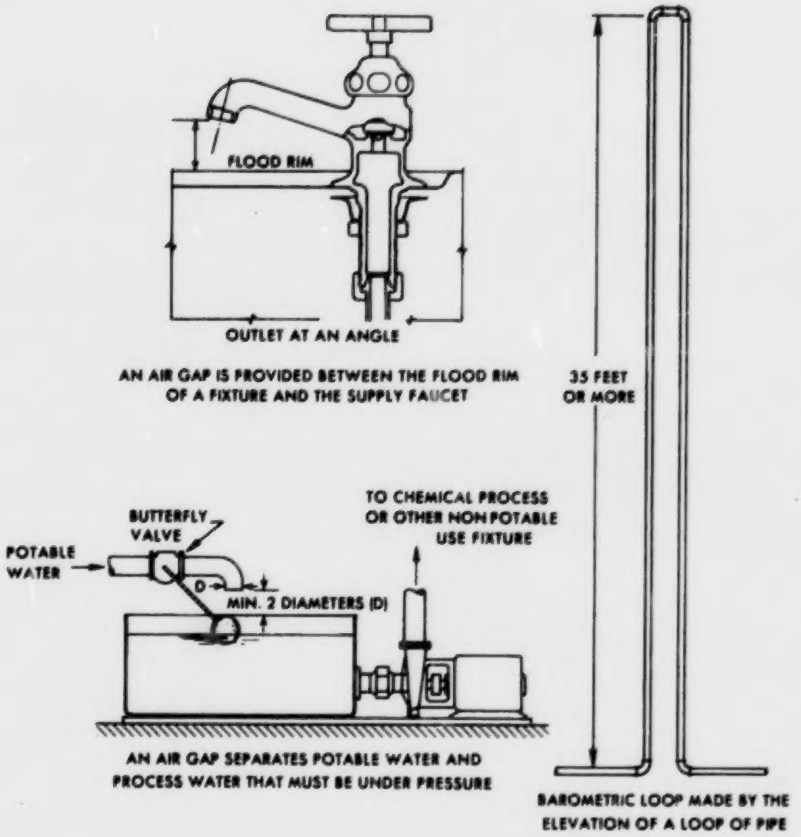

FLOOD RIM
OUTLET AT AN ANGLE
AN AIR GAP IS PROVIDED BETWEEN THE FLOOD RIM OF A FIXTURE AND THE SUPPLY FAUCET
35 FEET OR MORE
TO CHEMICAL PROCESS OR OTHER NON POTABLE USE FIXTURE
BUTTERFLY VALVE
POTABLE WATER
D
MIN. 2 DIAMETERS (D)
AN AIR GAP SEPARATES POTABLE WATER AND PROCESS WATER THAT MUST BE UNDER PRESSURE
BAROMETRIC LOOP MADE BY THE ELEVATION OF A LOOP OF PIPE

Figure 2. Showing Examples of the Air Gap and the Barometric Loop

Work began in 1938 to develop a national standard for air gaps in water distribution piping systems suitable for all water-connected devices and fixtures. The initial American Standard ASA 40.4 - 1942 for air gaps was recently updated to be ANSI A112.1.2 - 1973. [26].

A sketch of a barometric loop is also shown in Figure 2. Following the principle of operation, an elongated U-bend in the water piping is extended to a height beyond which siphonic action can not occur. In practical application the top of the U-bend would be about 35 feet above the highest outlet supplied by the water piping.

De Roos and Michaelsen [27] studied the barometric loop and particularly the air-lift effect [5/] which, should it occur in the simple loop, could make the piping arrangement ineffective at preventing backsiphonage. In their experiments they installed an air-water separator in the base of the loop on the downstream side and vented the separator through 1/2-inch copper tubing to the top of the downstream leg of the loop. Properly designed, it appears from that research that air entering the piping downstream of the separator will be removed by the separator-vent arrangement and will not enter the downstream leg of the loop to create the air-lift effect.

Additional matters of concern were not explored by the experiments but were noted by the authors:

1. It was not determined whether or not diffusion caused a transfer of contaminants from the downstream to the upstream side of the loop.
2. Any effect temperature gradients might have on the transfer of contaminants over the loop was not determined, and
3. Unanswered is the question of the amount of contamination transferred over the loop by air separated from water near the top of the loop.

For specific applications the barometric loop could be an inexpensive way to protect against backsiphonage. It can not be used when there is any possibility of back pressure occurring on the downstream side.

---

[5/] On the air-lift effect, air enters the downstream leg of the loop through an open outlet or leaky connection. An air bubble of sufficient size may form to rise in the pipe and lift a quantity of water over the U-bend into the potable water.

### 2.4.1 Backflow prevention devices

A backflow preventer has been defined as any mechanical device, whether used singly or in combination with other controls, that will automatically forestall the possibility of an unintentional reverse flow in a potable water distribution system. Depending upon the degree of redundancy desired, each backflow preventer is comprised of one or more check valves, atmospheric relief valves (air inlet valves) or pressure differential relief valves, together with test cocks and gate valves. Among the less complicated devices are the vacuum breakers which are used primarily to protect against the hazard of back-siphonage.

Three standards for vacuum breakers have originated with the American Society of Sanitary Engineering (ASSE) to cover the pipe-applied atmospheric-type [20], the hose-connection type [21] and the pressure-type [25] vacuum breakers. The International Association of Plumbing and Mechanical Officials (IAPMO) has published a standard for backflow prevention devices [28] which includes design and operational specifications together with laboratory and/or field test procedures for the pipe-applied atmospheric type, the single check valve pressure type and the double check valve pressure-type vacuum breakers. Also in the fifth edition of the Manual of Cross-Connection Control [29] published by the Foundation for Cross-Connection Control and Hydraulic Research (FCCCHR), specifications and test procedures for pressure type vacuum breakers have been included for the first time.

A.S.S.E. also has published a standard for Water Closet Anti-siphon Ball Cocks [30]. In this standard the anti-siphon device may be an air gap or a vacuum breaker.

In Figure 3, sketches and schematic drawings are used to aid the reader in the differentiation of the several types of vacuum breakers using combinations of atmospheric relief valves, check valves, and gate valves. The pipe-applied atmospheric type and the hose-connection type are designed for use downstream of the last flow control valve. With the pressure type vacuum breaker a control valve may be located downstream of the device.

Test cocks are an integral part of the device in some designs. They are required for double check valve assemblies and for reduced-pressure principle backflow prevention devices.

Table 3 summarizes the sizes, working pressures,temperature services, operational features and applications for each type of backflow preventer identified by an illustration and the corresponding A.S.S.E. standard number.

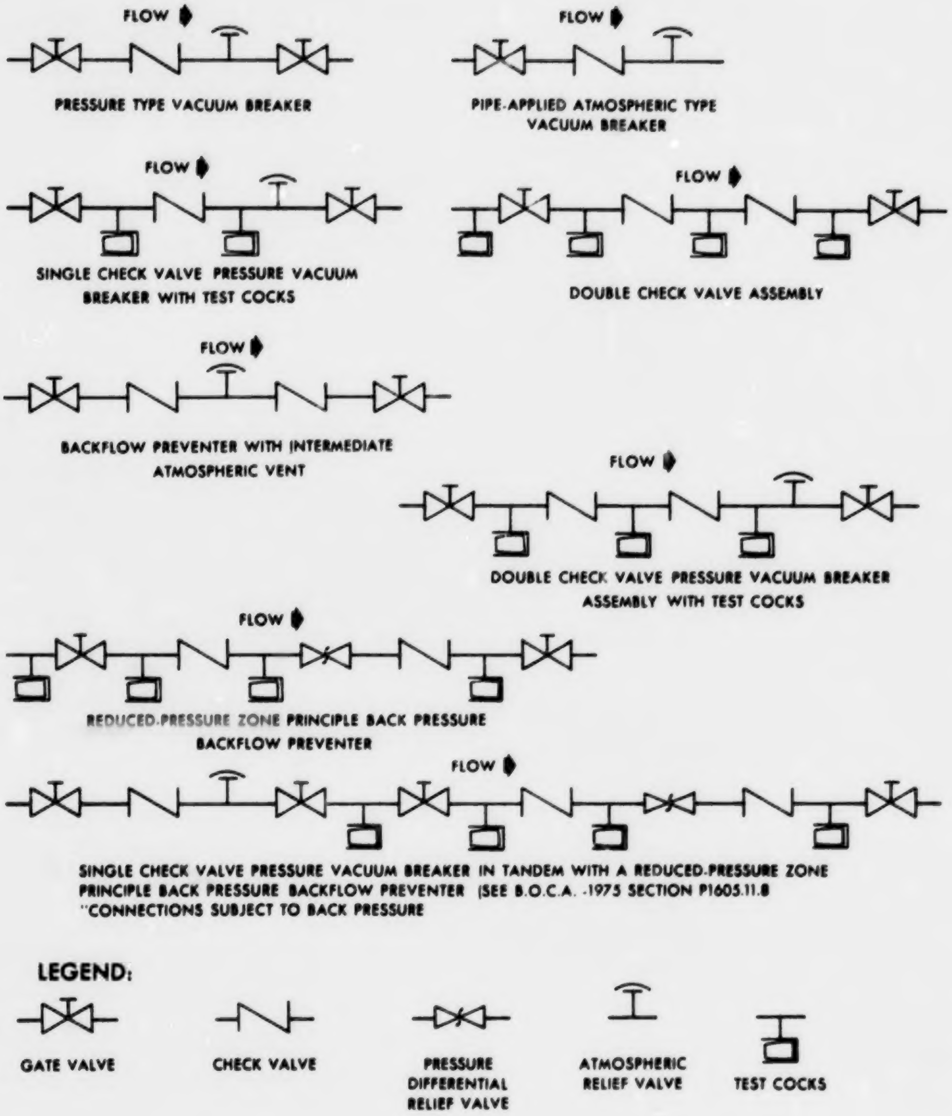
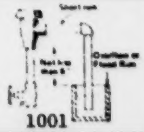
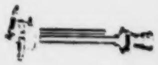
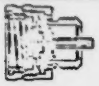
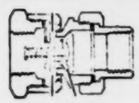
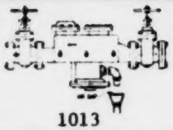
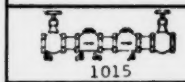
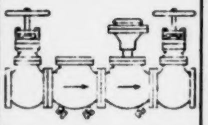

FLOW
PRESSURE TYPE VACUUM BREAKER
FLOW
PIPE-APPLIED ATMOSPHERIC TYPE VACUUM BREAKER
FLOW
SINGLE CHECK VALVE PRESSURE VACUUM BREAKER WITH TEST COCKS
FLOW
DOUBLE CHECK VALVE ASSEMBLY
FLOW
BACKFLOW PREVENTER WITH INTERMEDIATE ATMOSPHERIC VENT
FLOW
DOUBLE CHECK VALVE PRESSURE VACUUM BREAKER ASSEMBLY WITH TEST COCKS
FLOW
REDUCED-PRESSURE ZONE PRINCIPLE BACK PRESSURE BACKFLOW PREVENTER
FLOW
SINGLE CHECK VALVE PRESSURE VACUUM BREAKER IN TANDEM WITH A REDUCED-PRESSURE ZONE PRINCIPLE BACK PRESSURE BACKFLOW PREVENTER (SEE B.O.C.A. -1975 SECTION P1605.11.8 "CONNECTIONS SUBJECT TO BACK PRESSURE
LEGEND:
GATE VALVE
CHECK VALVE
PRESSURE DIFFERENTIAL RELIEF VALVE
ATMOSPHERIC RELIEF VALVE
TEST COCKS

Figure 3. Schematic Drawings of Backflow Prevention Devices that Utilize Check Valves, Gate Valves, Relief Valves and Test Cocks

Table 3. A Summary of the Backflow Prevention Devices Covered by A.S.S.E. Standards, Showing Application, Sizes, Working Pressures and Operational Features.

| Identification by A.S.S.E. No. | Application of the Device | Sizes | Working Pressure | Temperatures | | Operational Features of the Device |
|---|---|---|---|---|---|---|
| | | | | Cold | Hot | |
|  1001 | For prevention of backsiphonage when installed on discharge side of the control valve,at least 6 inches above flood level rim of the receptacle that is served, and when backflow source is subject only to normal atmospheric pressure. | 1/8" to 4" i.p.s. | 125 p.s.i minimum | between 32 and 110 °F | between 32 and 210 °F | Consists of a check valve (or similar moving member) and a relief valve on the discharge side of the check valve (or moving member) which opens to the atmosphere when the pressure in the line drops to atmospheric. |
|  1002 | The antisiphon water closet flush tank ball cock is a water supply valve opened and closed by means of a float or similar device and is used to supply water to a water closet flush tank. | 3/8" i.p.s. | 125 p.s.i. minimum | between 32 and 110 °F | | The ball cock is equipped with an antisiphon device in the form of an approved air gap, mechanical backflow preventer, or vacuum breaker which is an integral part of the ball cock unit and which is positioned on the discharge side of the water supply control valve. |
|  1011 | For prevention of backsiphonage or backflow from back pressure resulting from a hose terminal end being elevated above the hose cock simultaneously with loss of pressure in the line. | 3/4" and 1" hose | 125 p.s.i. minimum | between 32 and 195 °F | between 32 and 195 °F | Consists of a check valve member force loaded (or biased) to a closed position and an atmospheric vent valve, or means, force loaded (or biased) to an open position when the device is not under pressure. |
|  1012 | For prevention of backflow from backsiphonage or back pressure when the risk is of low hazard, or where the piping from the outlet of the device is submerged in a vessel under atmospheric pressure.<br>For continuous or intermittent service. | 1/4" to 3/4" i.p.s. | 150 p.s.i. minimum | between 40 and 210 °F | between 40 and 210 °F | Consists of two independently operating check valves separated by an intermediate chamber with a means for automatically venting it to atmosphere. The check valves are force loaded to a normally closed position and the venting means is force loaded to normally open position. |
|  1013 | For prevention of backflow in potable water supply lines when subjected to back pressure. Some designs of these devices protect somewhat against backsiphonage. All are designed to operate under continuous pressure conditions. | 1/2" to 16" i.p.s. | 150 p.s.i. minimum | between 33 and 110 °F | between 33 and 210 °F | Consists of two independently acting check valves, internally force loaded to a normally closed position,and separated by an intermediate chamber (or zone) in which there is an automatic relief means for venting to atmosphere ,internally force loaded to a normally open position. |
|  1015 | For protection against backflow into potable water lines subject to back pressure where risk is no health hazard. | Same as above | Same as above | Same as above | Same as above | Consists of two independently acting check valves internally force loaded to a normally closed position. |
|  1020 | For protection of potable water supply lines against backsiphonage only. Not for use in any system where there can be back pressure applied to the device.<br>It has a built-in means to mechanically force the atmospheric vent valve to open should a negative pressure(vacuum) be created in the supply line. | 1/2" to 10" i.p.s. | 150 p.s.i. minimum | between 33 and 110 °F | between 33 and 210 °F | Sizes 2" and smaller consist of at least one check valve and an automatic vent valve opening to atmosphere positioned downstream of the check valve and located between two shutoff valves.<br>Sizes above 2" are units consisting of at least two check valves and an automatic vent opening to atmosphere, positioned downstream of the check valves and located between two shutoff valves. |

# 3. ELEMENTS IN THE EVALUATION OF BACKFLOW PREVENTION DEVICES

## 3.1 The Product Standards

The first widely used standards for backflow preventers appears to be those of the Foundation for Cross-Connection Control Research at the University of Southern California. The other entries in the standards field were A.W.W.A. [31], A.S.S.E. [20,21,22,23,24,25,30] and I.A.P.M.O. [28].

### 3.1.1 Foundation for Cross-Connection Control and Hydraulic Research (FCCCHR)

The 5th edition, (March,1974) of the Manual of Cross-Connection Control [29] incorporated editing of Section 10 to make the original intent of the formulating committee a bit clearer. Also in Sections 9 and 10, the pressure type vacuum breakers were included for the first time. The Manual is a volume of 150 pages compiled to provide for uniform cross-connection control practices as they impact upon health agencies, water purveyors, water users (consumers) and inspectors of backflow prevention devices. The following subjects are included:

- A statement of policy
- Responsibilities of purveyors,consumers and officials
- Definitions of words and phrases
- Examples of cross connections
- Results of noncompliance
- Cross-connection control practices
- Samples of standard letters and forms
- Field testing procedures
- Specifications for devices
- Case histories

The survey made by the Navy [11] in 1968, summarized in Table 2 gives some idea of the extent of use of this particular cross-connection control manual throughout the United States.

### 3.1.2 American Water Works Association (AWWA or A.W.W.A.)

The A.W.W.A. has a standard, C 506-69, [31] for two types of devices that are designed especially for protection of water in the water mains. The work toward development of the standard appears to have started in 1959 with the first output being a manual: "AWWA M14 - Recommended Practices for Backflow Prevention and Cross-Connection Control."

The subsequent AWWA standard C 506-69"Backflow Prevention Devices - Reduced Pressure Principle and Double Check Valve Types" describes essentially the same devices as does A.S.S.E. 1013 and 1015.

### 3.1.3 American Society of Sanitary Engineering (ASSE or A.S.S.E.)

In 1953 the Standards Committee of A.S.S.E. was appointed. The output of backflow prevention standards began in 1964 with A.S.S.E. 1001 [20] and A.S.S.E. 1002 [30], followed later in 1970 by A.S.S.E. 1011 [21], in 1971 by A.S.S.E. 1013 [23], in 1972 by A.S.S.E. 1012 [22] and A.S.S.E. 1015 [24]; and the latest A.S.S.E. 1020 [25] in 1974. The Canadian Standards Association voted to adopt these standards as the basis for their standards.

### 3.1.4 International Association of Plumbing and Mechanical Officials (IAPMO or I.A.P.M.O.)

The IAPMO standards are related to the need for backflow preventer standards in the IAPMO Plumbing Code. In the development of the IAPMO Specification PS 31-74 [28] many of the advisors to the FCCCHR programs, including Dr. Springer, aided in formulating the standard. Four types of backflow preventers are identified with criteria and test requirements: Reduced-pressure principle backflow prevention device, Double check valve assembly, Single check valve pressure vacuum breaker, and Double check valve pressure vacuum breaker assembly.

### 3.1.5. Summary of Applications of Product Standards

Table 4 is a matrix arrangement of the information found in plumbing codes and various other publications relating the type of backflow preventer (identified by standard when available) to the type of hazard at a cross-connection. This table illustrates how these complex relationships can be visually presented. When the environmental, engineering and economic considerations are sharply defined for each specific application, the blanks and the small squares (indicating acceptable applications) and the large squares (indicating primary applications) might fit into different cells from those shown in table 4. The absence of a square, therefore, does not necessarily mean that such application is undesirable.

## 3.2 The Plumbing Codes

Some regulation of cross-connection hazards is provided by the ordinances or the state laws that adopt model plumbing codes. Model plumbing codes have been developed by the following sponsors:

American Society of Plumbing Engineers (ASPE) with the
National Association of Plumbing-Heating-Cooling Contractors
1016 20th Street, N.W., Washington, D.C. 20036 (NAPHCC)

Table 4. A Matrix Arrangement of the Information Found in Plumbing Codes and Various Other Publications, Relating the Type of Backflow Preventer to the Type of Hazard at a Cross-Connection.

| Backflow Prevention Devices | Air Gaps | Barometric Loops | Atmospheric Type Vacuum Breakers | | | Pressure Type Vacuum Breakers | | | | Backflow Preventers with | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pipe Appl'd | Ball Cock | Hose Conn. | Single Check | | Double Check | | Atmospheric Vent | Reduced Pressure Principle Back Pressure | | | Double Check Valve Assemblies | | |
| Standards for Backflow Prevention Devices / Backflow Prevention Applications | ANSI A 112.1.2 1942 (R1973) | (No Standard) | ANSI A 112.1.1 1971 | A.S.S.E. 1002 1968 | A.S.S.E. 1011 1970 | IAPMO PS 31 1974 | A.S.S.E. 1020 1974 | IAPMO PS 31 1974 | A.S.S.E. 1020 1974 | A.S.S.E. 1012 1972 | A.S.S.E. 1013 1971 | AWWA C 506 1969 | IAPMO PS 31 1974 | A.S.S.E. 1015 1972 | AWWA C 506 1969 | IAPMO PS 31 1974 |
| Direct connection to pumps, tanks, or lines handling sewage and toxic substances | ☐ | | | | | | | | | | ☐ | ☐ | ☐ | | | |
| Direct connection through steam lines and boilers to toxic substances | ☐ | | | | | | | | | | ☐ | ☐ | ☐ | | | |
| Direct connection in car wash installation<br>Inlet type connection in greenhouse | | ☐ | | | | | | | | | ☐ | ☐ | ☐ | | | |
| Direct connection to pumps, tanks, lines, or steam boilers involving only nontoxic substances | ☐ | | | | | | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Inlet connection to coils or jackets used as heat exchangers in compressors, etc. (toxic substances) | ☐ | | ☐ | | | | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | | |
| Low inlet to receptacles containing toxic material<br>Valve outlets or fixtures with hose attachments | ☐ | ☐ | ☐ | | ☐ | ☐ | ☐ | ☐ | ☐ | | | | | | | |
| Low inlet to receptacles (nontoxic substances)<br>Lawn sprinkler systems and hose connections | ☐ | ☐ | ☐ | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Flush valve toilets (not subject to back pressure) | | | ☐ | | | | | | | | | | | | | |
| Toilet and urinal tanks (not subject to back pressure) | ☐ | ☐ | | ☐ | | | | | | | | | | | | |
| Fire fighting systems without chemical additives | | | | | | | | | | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Inlet type connections to plating tanks, stripping, degreasing, or dipping tanks (no back pressure) | ☐ | | | | | ☐ | ☐ | ☐ | ☐ | | ☐ | ☐ | ☐ | | | |
| Lawn sprinkler systems with fertilizer injection<br>Water-cooled equipment which is sewer connected | | | | | | | | | | | ☐ | ☐ | ☐ | | | |
| Firefighting systems which are treated for algae, or scale formation, or contain anti-freeze | | | | | | | | | | | ☐ | ☐ | ☐ | | | |
| Steam cookers and sterilizers<br>Mixing tees using steam and water | | | | | | | | | | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Building Officials and Code Administrators International
Inc. (BOCA or B.O.C.A.)
1313 East 60th Street, Chicago, Illinois 60637

International Association of Plumbing and Mechanical
Officials (IAPMO or I.A.P.M.O.)
5032 Alhambra Avenue, Los Angeles, California 90032

Southern Building Code Congress International, Inc
3617 Eighth Avenue, South, Birmingham, Alabama 35222

In those localities where plumbing codes have been adopted into law, plumbing inspectors are employed to effectuate the requirements of the code. As technology and economics interact, products such as backflow prevention devices are modified or new ones are introduced. In either case the compilers of plumbing codes are called upon to make changes in the codes so that acceptable innovations may be passed by the plumbing inspector. The procedures for making changes varies with each of the sponsors and is a time consuming operation.

At the Annual Meeting of the A.S.S.E. in 1974 representatives of the four model codes gave the following brief descriptions of procedures for making code changes as recorded in the 1974 A.S.E.E. Yearbook:

Milton Snyder, Chairman of the Joint NAPHCC-ASPE Plumbing Code committee stated:

"Changes and additions to the National Standard Plumbing Code can be made upon initiation by Code Committee members or can be initiated by any interested party. There are public meetings at least once a year. Chairmanship of the committee rotates between the National Association of Plumbing Contractors and the American Society of Plumbing Engineers. Actions of the committee are submitted to our Board of Directors and annually the actions of the Board are submitted to the entire membership. Since our membership has a broad base of Contractors, Engineers, and Inspectors -- all of whom vote -- we cannot conceive that any model code has a broader base of members with full voting privileges. And there is of course another review by any locality using our information."

Clarence R. Bechtel, Managing Director of BOCA spoke to the point:

"Code changes can be submitted by anyone on forms supplied by BOCA. The Plumbing Code is not changed by staff, only BOCA members change BOCA codes. The Plumbing Code changes are reviewed in a public hearing and followed by a vote of active members. The approved changes are then incorporated into the code.

The code is established and maintained according to National Standards and practices, that is a system or device acceptable in a distant community should be acceptable in another community providing the performance can be proven to be identical. The local or regional influence is minimized.

The responsibility for enforcement lies solely and ultimately with the local municipality.

The individuals with the duty and responsibility of enforcing the code in the local level have a voice and a vote in determining the content of the code by a democratic process.

Our technical staff provides the necessary back-up services such as code interpretations, plumbing code seminars and a plumbing code correspondence course to enhance the officials knowledge and use of the code."

R.E. Sullivan, Director of Education for Southern Building Code Congress International spoke as follows:

" We believe that a code can best be written and amended by those people who use it from day to day, utilizing the advice and assistance made available from industry and the architectural and engineering professions. Consequently, every member of the Southern Building Code Congress is afforded the opportunity to participate in the revision process at every annual research conference, and to vote on code changes recommended by our code revision committee."

Neil A. Mac Lean, Executive Vice President of I.A.P.M.O.

"Our code changes procedure is not much different from that of any other code agency other than the fact that - and this may be true of the other agencies but it wasn't brought out - we will accept a code change from anyone in the world, anyone. When we receive a code change to the Uniform Plumbing Code, it is printed just the way it is submitted to us by the photocopier. We don't take a chance that in retyping that we may change your words. We use a photocopier to reproduce enough copies of these code changes for the code changers committee. We have a deadline of March 1st of each year, and all code changes that have come in prior to March 1st, usually by the 1st of April are reviewed by a cross section of the code changing committee; still having the only voting privilege are people who have a nonvested interest, the inspectors from our jurisdiction. The code change receives a recommendation at that point, a recommendation to either accept, reject, or hold for further study. Within 30 days prior to the annual conference - but more actually, usually within 30 days after that code changes committee - all of these code changes are then printed in a code changes document and mailed out to our entire membership, or to anyone else if they have an interest in the Uniform Plumbing Code - they may not be a member. These changes are then voted on at the conference, and we have remained anonymous in these code changes."

"We specify that a code change has to be done in a specific manner, and if a stranger to our code-changes procedure submits a code change to us, and it is incorrect, we inform him of how to do it correctly and assist him to do it correctly. We then make it anonymous.

### 3.2.2 Backflow prevention requirements in model plumbing codes

The plumbing codes determine the utilization of backflow preventers in a building at the time of the design of the structure. An effective cross-connection control program must encourage the designers to install suitable devices,where needed, at the time of construction to obviate the resistance to change later.

Table 5 presents a listing of paragraphs from four model plumbing codes pertinent to specific types of cross-connections.

### 3.3 The Manufacturers of Backflow Prevention Devices

A complete listing of manufacturers of all backflow prevention devices is beyond the scope of this document. In table 6 the names of manufacturers have been compiled from the latest listings of approved devices of the American Society of Sanitary Engineering and from a similar list of the Foundation for Cross-Connection Control and Hydraulic Research. Additional names were obtained from advertisements found in recent technical publications and magazines.

In table 7, the matrix presentation is only as up-to-date as our source of information.

### 3.4 Testing Laboratories

There currently exist two modes for the certification of backflow prevention devices. The Foundation for Cross-Connection Control and Hydraulic Research tests for compliance of backflow prevention devices with criteria published in its Manual of Cross-Connection Control [29]. The American Society of Sanitary Engineering has working arrangements with three testing laboratories to test devices and to authorize a seal of approval. Just recently a procedure for accrediting testing laboratories was established within the Department of Commerce, effective February 25, 1976. The complete procedure, as published in the Federal Register of Wednesday, February 25, 1976 has been arranged by the authors of this document to provide sidenotes and a special format as explained in Appendix Section 10.3.

Each of the above procedures will be discussed in the following paragraphs.

Table 5. A Listing of Paragraphs from Four Model Plumbing Codes Pertinent to Specific Types of Cross Connections

| Points of Contact Where a Potable Water System May Become Contaminated by Backflow from a Non-potable Source | B.O.C.A. 1973 Code Paragraphs | I.A.P.M.O. 1973 Code Paragraphs | PHCC-ASPE 1973 Code Paragraphs | S.B.C.C. 1973 Code Paragraphs |
|---|---|---|---|---|
| Water Closet Flushometer Valves ; Urinal Flushometer Valves | 1605.117 | 1003(a),(c) | 10.5.5A | 1205.1 |
| Water Closet and Urinal Tanks | 1605.117 | 1003(b) | 10.5.5A | 1205.2 |
| Over Rim Supplies to Plumbing Fixtures | 1605.111 | 1003(d) | 10.5.2 | 1205.3 |
| Direct Connections Between Potable Water Piping and Sewer Connected Wastes | 1605.8 | 1003(e) | 10.5.3.5c | |
| Connections Between Potable Water Piping and the Inlet Side of a Fixture Trap | | 1003(e) | | |
| Inlets to Tanks, Vats, Sumps and other Receptors | 1605.116 | 1003(g) | 10.5.3.1 | |
| Lawn Sprinkling Systems | 1605.117 | 1003(h) | 10.5.9 | 1205.4 |
| Fixture Inlets or Valved Outlets with Hose Attachments | 1605.117 | 1003(i) | 10.5.3.3 | 1205.5 |
| Medical, Therapeutic, Surgical, Mortuary or Similar Equipment | 1403.6;.7 | 1003(j) | 14.27;.28 | |
| Water Cooled Compressors, Degreasers or any other Water Cooled Equipment | | 1003(k) | 10.5.3.4 | |
| Water Cooled Equipment Subject to Continuous Flows for Periods of Twelve Hours or More | | 1003(k) | 10.5.3.4 | |
| Aspirators Connected to the Inlet Side of a Fixture Trap | 1403.6 | 1003(l) | 10.5.5A | |
| Steam Boilers,Pumps, etc. that May Create a Higher Pressure in the Non-potable Line than Exists in the Potable System | 1605.117 | 1003(n)(o) | 10.5.3.5 | 1205.6 |
| Cup Beverage Vending Machines | 1605.117 | | 10.5.5A | |
| Dishwashing,Garbage Can Cleaning, and Laundry Machines | 1605.117 | | 10.5.5A | 1204.3 |
| Hose Bibbs | 1605.117 | | 3.1.3 | 1205.5 |
| Mobile Homes in Trailer Parks | | E 25 | 18.5.8 | C 8(c) |
| High Pressure Units such as Used in Car Washes to Supply Water and Detergent Under High Pressure | | | | Dwg. 11 |

NOTE:

B.O.C.A. is Building Officials and Code Administrators International. Inc.

I.A.P.M.O. is International Association of Plumbing and Mechanical Officials

PHCC-ASPE is National Association of Plumbing, Heating, Cooling Contractors joined with the American Society of Plumbing Engineers.

S.B.C.C. is Southern Building Code Congress International, Inc.

Table 6. An Alphabetical Listing of Manufacturers of Backflow Prevention Devices. (Relate to Table 7)

**AMA Enterprises, Inc.**
**444 Hempstead Turnpike**
**West Hempstead, New York 11552**
**(516) 483-1166**

**Alsons Products Corp.**
**525 East Edna Place**
**Covina, Calif. 91722**
**(213) 966-1668**

**American-Standard, Inc.**
**P. O. Box 2003**
**New Brunswick, New Jersey 08903**
**(201) 885-1900**

**Badger Meter, Inc.**
**4545 W. Brown Deer Road**
**Milwaukee, Wisconsin 53223**
**(414) 355-0400**

**Beacon Valve Company**
**P. O. Box 478, 2 Jackson St.**
**Waltham, Mass. 02154**
**(617) 893-0011**

**Belvedere Products, Inc.**
**725 Columbia Avenue**
**Belvidere, Illinois 61008**
**(815) 544 3131**

**Bidoro Manufacturing Co.**
**229 Bellerose Avenue**
**East Northport, N. Y. 11731**
**(516) 261-5050**

**Buckner Sprinkler Co.**
**909 W. Nielson Avenue**
**Fresno, California 93706**
**(209) 269-5561**

**Burlington Brass Works**
**400 Pine Street**
**Burlington, Wisconsin 53105**
**(414) 763-3534**

**A. W. Cash Valve Mfg. Corp.**
**666 E. Wabash Avenue**
**Decatur, Illinois**
**(217) 422-8574**

**Champion Brass Mfg. Co.**
**1460 Naud Street**
**Los Angeles, California 90012**
**(213) 221-2108**

**Chicago Faucet Co.**
**2100 S. Nuclear Dr.**
**Des Plains, Illinois 60018**
**(312) 298-1140**

**Chicago Speciality Mfg. Co.**
**7500 Linder Avenue**
**Skokie, Illinois 60076**
**(312) 674-7500**

**Cla-Val Co. Backflow Div.**
**Post Office Box 1325**
**Newport Beach, California 92663**
**(714) 548-2201**

**Clayton Mark & Co.**
**1900 Dempster Street**
**Evanston, Illinois 60204**
**(312) 864-9100**

**Consolidated Brass Co.**
**P. O. Box 247**
**Mathews, North Carolina**
**(704) 847-9191**

**Coyne & Delany Co.**
**1565 Avon Street Extended**
**Charlottesville, Virginia 22901**
**(804) 296-0166**

**Crane Company**
**300 Park Avenue**
**New York, N. Y. 10022**
**(212) 752-3600**

**Eastman Central D Div.**
**U. S. Brass Corp. P. O. Box 37**
**Plano, Texas 75074**
**(214) 235-4531**

**Fluidmaster Inc.**
**1800 Via Burton, P. O. Box 4264**
**Anaheim, California, 92803**
**(714) 774-1444**

**Frost Company**
**14th Ave. at 65th Street**
**Kenosha, Wisconsin 53140**
**(414) 658-4301**

**G. C. G. Mfg. Co. Ltd.**
**173 Glidden Road, BRAMPTON,**
**Ontario, Canada L6W 3L9**
**(416) 453-8120**

**H. L. Gee Mfg. Co.**
**9292 Santa Monica Blvd. P. O. Box 5285**
**Beverly Hills, California 90210**
**(213) 275-5376**

**Griswold Controls**
**124 E. Dyer Road**
**Santa Ana, California 92707**
**(714) 546-3844**

Table 6. (Continued)

Hamilton Industries Division
American Hospital Supply Co.
Two Rivers, Wisconsin 54241
(414) 793-1121

Hersey Products Inc.
250 Elm Street
Dedham, Massachusetts 02026
(617) 326-9400

ITT Grinnell Corp.
260 W. Exchange Street
Providence, Rhode Island 02901
(401) 831-7000

Jaco, Inc.
2945 W. Maple Road
Troy, Michigan 48084
(313) 647-0115

Johns-Manville Corp.
Greenwood Plaza
Denver, Colorado 80217
(303) 770-1000

Josam Manufacturing Co.
Corymbo Road
Michigan City, Indiana 46360
(219) 872-5531

Kirkhill, Inc.
12021 Woodruff Avenue
Downey, California 90248
(213) 773-3492

Kohler Company
44 High Street
Kohler, Wisconsin 53044
(414) 457-4441

Lawler ITT
3500 N. Spaulding Avenue
Chicago, Illinois 60618
(312) 267-1600

Lear Siegler, Inc.
6331 E. Jefferson Avenue
Detroit, Michigan 48207
(313) 259-2095

Mansfield Sanitary, Inc.
P. O. Box B
Perrysville, Ohio 44864
(419) 938-5211

Modern Faucet Mfg. Company
1700 East 58th Place
Los Angeles, California 90001
(213) 582-6286

Mueller Steam Specialty Company
72 Jericho Turnpike
Mineola, New York 11501
(516) 747-8300

L. R. Nelson Corporation
7719 N. Pioneer Lane
Peoria, Illinois 61614
(309) 692-2200

Nepture Water Meter Company
30 Perimeter Park
Atlanta, Georgia 30341
(404) 458-8111

Nibco, Inc.
500 Simpson Avenue
Elkhart, Indiana 46514
(219) 295-3000

Nidel Company
P. O. Box 418
Grand Haven, Michigan 49417
(616) 842-2650

Powers Regulator Company
3400 Oakton Street
Skokie, Illinois 60076
(312) 673-6700

Rain Bird Sprinkler Mfg. Co.
7045 N. Grand Avenue
Glendora, California 91740
(213) 963-9311

Rockwell International Corp.
P. O. Box 487
Uniontown, Pennsylvania 15401
(412) 438-3501

Sloan Valve Company
10500 Seymour Avenue
Franklin Park, Illinois 60131
(312) 671-4300

Surgical Mechanical Research, Inc.
960 W. 16th Street
Newport Beach, California 92663
(714) 646-4405

Taco, Inc.
1160 Cranston Street
Cranston, Rhode Island 02920
(401) 942-8000

Tempstat Corporation
Monument Road
Hinsdale, New Hampshire 03451
(603) 256-6001

Table 6. (Continued)

T & S Brass And Bronze Works, Inc.
119 Magnolia Avenue
Westbury, L. I., New York 11590
(516) 334 5104

Toro Technology
1709 La Costa Meadows Drive
San Marcos, California 92069
(714) 744-5650

Twentieth Century Products Corp.
3600 South Jason Street
Englewood, Colorado 80110
(303) 789-0418

Water Saver Faucet Company
701 W. Erie Street
Chicago, Illinois 60610
(312) 666-5500

Watts Regulator Company
10 Embankment Street
Lawrence, Massachusetts 01842
(617) 688-1811

Wolverine Brass Works
648 Monroe Avenue, N. W.
Grand Rapids, Michigan 49502
(616) 451-2581

Woodford Mfg. Company
1626 Delaware Avenue
Des Moines, Iowa 50317
(515) 262-5638

Zurn Industries, Inc.
1801 Pittsburgh Avenue
Erie, Pennsylvania 16512
(814) 455-0921

Table 7. A Matrix Presentation Relating Manufacturers with the Types of Backflow Prevention Devices that Each Manufactures.

| Types of Backflow Preventers | Air Gap | Atmospheric Type Vacuum Breakers | | | Pressure Type Vacuum Breakers | | | | Backflow Preventers | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Intermediate | Double Check | | Reduced Pressure Principle | |
| Representative Standards / Makers of Backflow Preventers | ANSI A 112.1.2 1973 | Pipe Applied ANSI A 112.1.1 1971 | Antisiphon Ball Cock A.S.S.E. 1002 1963 | Hose Connection A.S.S.E. 1011 1970 | Single Check Valve IAPMO PS 31 1974 | Single Check Valve A.S.S.E. 1020 1974 | Double Check Valve IAPMO PS 31 1974 | Double Check Valve A.S.S.E. 1020 1974 | Atmospheric Vent A.S.S.E. 1012 1972 | Valve Assemblies IAPMO PS 31 1974 | Valve Assemblies A.S.S.E. 1015 1972 | IAPMO PS 31 1974 | A.S.S.E. 1013 1971 |
| Alsons Products Corp | | N | | | | | | | | | | | |
| AMA Enterprises | | | N | | | | | | | | | | |
| American Standard, Inc. | | N | N | | | | | | | | | | |
| Badger Meter, Inc. | | | | | | | | | | | | | & |
| Beacon Valve Company | | N | | | | | | | | | | | |
| Belvedere Products, Inc. | | # | | | | | | | | | | | |
| Bidoro Manufacturing Co. | | N | | | | | | | | | | | |
| Buckner Sprinkler Co. | | | | | N | | | | | | | | |
| Burlington Brass Works, Inc. | | | N | | | | | | | | | | |
| A.W.Cash Valve Mfg.Corp. | | # & | | & | | | | | & | | | | |
| Champion Brass Mfg. Co. | | # | | | | | | | | | | | |
| Chicago Faucet Company | | # | | | | | | | | | | | |
| Chicago Specialty Mfg. Co. | | | N | | | | | | | | | | |
| Cla-Val Co., Backflow Div. | | | | | | | # | | | # | | # | |
| Clayton Mark & Co. | | | | & | | | | | | | | | |
| Consolidated Brass Co. | | # & | | | | | | | | | | | |
| Coyne & Delany Company | | N | | | | | | | | | | | |
| Crane Company | | N | N | | | | | | | | | # | |
| Eastman Central D Div. | N | N | | | | | | | | | | | |
| Fluidmaster, Inc. | | | N | | | | | | | | | | |
| Frost Company | N | | | | | | | | | | | | |
| G. C. G. Mfg. Co., Ltd. | | | | | | | | | & | | | | |
| H. L. Gee Mfg. Co. | | # | | | | | | | | | | | |
| Grinnell Company, Inc. | | | | | | | | | | # | | | |
| Griswold Controls | | | | | | | | | | | & | | & |
| Hamilton Industries Div. | | N | | | | | | | | | | | |
| Hersey Products, Inc. | | | | | | | # | | | # | | # | |
| Jayco, Inc. | | N | | | | | | | | | | | |

Meaning of Symbols: # = FCCCHR Listed & = A.S.S.E. Listed N = Advertized but not listed

Table 7 (Continued)

| Types of Backflow Preventers | Air Gap | Atmospheric Type Vacuum Breakers | | | Pressure Type Vacuum Breakers | | | | Backflow Preventers: Intermediate | Backflow Preventers: Double Check | | Backflow Preventers: Reduced Pressure Principle | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Representative Standards / Makers of Backflow Preventers | ANSI A 112.1.2 1973 | Pipe Applied ANSI A 112.1.1 1971 | Antisiphon Ball Cock A.S.S.E. 1002 1963 | Hose Connection A.S.S.E. 1011 1970 | Single Check Valve IAPMO PS 31 1974 | Single Check Valve A.S.S.E. 1020 1974 | Double Check Valve IAPMO PS 31 1974 | Double Check Valve A.S.S.E. 1020 1974 | Atmospheric Vent A.S.S.E. 1012 1972 | Valve Assemblies IAPMO PS 31 1974 | Valve Assemblies A.S.S.E. 1015 1972 | IAPMO PS 31 1974 | A.S.S.E. 1013 1971 |
| Johns-Manville Corp. | | | | | # | | # | | | # | & | # | & |
| Josam Manufacturing Co. | | | | N | | | | | | | | | |
| Kirkhill, Inc. | | | N | | | | | | | | | | |
| Kohler Company | | N | N | | | | | | | | | | |
| Lawler ITT | | | | | | | | | | | & | | & |
| Lear Siegler, Inc. | | | N | | | | | | | | | | |
| Mansfield Sanitary, Inc. | | | N | & | | | | | | | | | |
| Modern Faucet Mfg. Co. | | # | | | | | | | | | | | |
| Mueller Steam Specialty Co. | | & | | & | | | | | | | | | |
| L. R. Nelson Corporation | | & | | | | | | | | | | | |
| Neptune Water Meter Co. | | | | | | | | | | | & | | & |
| Nibco, Inc. | | | | & | | | | | | | | | |
| Nidel Company | | # | | & | | | | | | | | | |
| Powers Regulator Co. | | N | | | | | | | | | | | |
| Rain Bird Sprinkler Mfg.Co. | | # & | | & | | | | | & | | & | | & |
| Rockwell International Corp. | | | | | | | | | | | & | | & |
| Sloan Valve Company | | # & | | | | | | | | | | | |
| Surgical Mech. Research, Inc. | | # | | | # | | # | | | # | | | |
| Taco, Incorporated | | | | | | | | | & | | | | |
| Tempstat Corporation | | # | | | | | | | | | | | |
| T & S Brass & Bronze Works | | N | | | | | | | | | | | |
| Toro Technology | | | | | | | | | | | N | | N |
| Twentieth Century Products | | | & | | | | | | | | | | |
| Water Saver Faucet Company | | # | | | | | | | | | | | |
| Watts Regulator Company | | # & | | & | | | | N | & | | & | | & |
| Wolverine Brass Works | | | | & | | | | | | | | | |
| Woodford Mfg. Company | | | | & | | | | | | | | | |
| Zurn Industries, Inc. | | | | & | | | | | | | | | |

Meaning of Symbols: # = FCCCHR Listed & = A.S.S.E. Listed N = Advertized but not listed

### 3.4.1 Foundation for Cross-Connection Control and Hydraulic Research

It was mentioned in Section 2.2 that the Foundation for Cross-Connection Research was established as an arm of the University of Southern California in 1944. In a publication dated April, 1948 it was stated that the Research Foundation for Cross-Connection Control established at the University of Southern California is properly equipped to make all the necessary studies and tests on antisiphon and backflow prevention devices and has been engaged in the work since 1944.[12]

The name of the foundation was later changed to appear in the fourth edition of the Manual of Cross-Connection Control[15] as Foundation for Cross-Connection Control Research (FCCCR). In the latest edition of the Manual the name is given as Foundation for Cross-Connection Control and Hydraulic Research (FCCCHR). As reported by Bibbens [11]:

"A financial grant originally equipped the FCCCR laboratory and provided staff salaries for the first few years. Laboratory equipment and instrumentation were expanded and improved in following years through gifts from water equipment manufacturers. There is now a written agreement with the Southern California Water Utilities Association which provides financial support for the Foundation in the form of annual membership subscriptions by water utilities, cities, and county, state, and federal agencies. Memberships range from $50 to $500 per year, depending on utility size. The Southern California Water Utilities Association is a non-profit organization which supports an educational institution (the FCCCR)." [11]

"The FCCCR laboratory was originally located on the USC campus but was removed in the mid-1960's to make way for other campus expansion. Being without laboratory facilities for a few years, the FCCCR contracted for the use of private facilities when laboratory tests were required. In, 1968, the laboratory was reestablished in an old pumping station on Riverside Drive in Los Angeles. The FCCCR currently conducts backflow evaluation tests and other related research at this facility. Pressures of 45 and 150 psi are available directly from the city's water supply system. Headers up to 16" are installed for testing the various sizes of devices. A 200 HP diesel engine driven pump will soon be included in the system to provide a 4600 gpm recirculating flow capacity. The Foundation's laboratory was inspected by the NCEL Project Engineer in June 1969 and was found to have facilities adequate for the testing of backflow preventers as prescribed by the 4th Edition of the "Manual." During this inspection, it was observed that extensive equipment modification and improvement were underway and much new instrumentation was being installed in the laboratory. Half of the laboratory space was occupied by the Los Angeles Department of Water and Power for meter flow testing, but the remaining half of the laboratory had enough space for considerable future expansion by the FCCCHR for further testing or research." [11]

Summarizing from Dr. Springer's paper [32] for testing under the FCCCHR procedures, a proposer must:

" (a) Submit a complete set of drawings and specification to FCCCHR for review. If the review discloses that the design is weak or contradicts the specifications of FCCCHR, FCCCHR will make these weaknesses or non-compliance aspects known to the proposer.

(b) If the manufacturer or proposer passes step (a), he must then submit one device or preferably three devices to FCCCHR for laboratory evaluation. The device is inspected to see that it is in compliance with FCCCHR's specification and the manufacturer's drawings. The manufacturer is invited to have his representative present to witness the evaluation procedure and results.

(c) If the device(s) pass the hydraulic laboratory evaluation, the manufacturer must next arrange for the installation of at least three (3) devices of this same model and size in the field. The field location must be approved by FCCCHR (Such location(s) cannot be on fire service where static conditions may exist continuously from one year to the next). Also, a service where the flow is maximum continuously is not acceptable. Also the device under test cannot be placed in a position where it would be expected to protect the potable water supply against potential backflow of any hazardous materials or contaminant. Such contaminant could backflow if the unproven device failed. Also, the device cannot be placed in a water supply that cannot be shutoff temporarily as may be required during the field evaluation.

(d) The field installed devices are tested monthly:

-- The tightness of each check valve for double check valve assemblies is determined by test to see that each check will hold a 1 psig differential in the direction of flow.

-- The opening pressure differential of the relief valve, the pressure differential across number one check valve, and the drip tightness of number two check valve are all checked for the RPBD device."

(e) If any type of malfunction is observed during the field test, the test is terminated and such devices are returned to the manufacturer for corrective measures.

(f) After the device has been corrected or redesigned, the device must go through the complete hydraulic laboratory evaluation again just as though it were a completely new device. Then if a successful laboratory test is again realized, the device is field tested a second time. When the device satisfies FCCCHR requirements, the manufacturer receives a "Certificate of Approval" for the particular model and size of device passing the tests.

### 3.4.2 Laboratories testing in the A.S.S.E. Seal Program

The American Society of Sanitary Engineering (A.S.S.E.) was established in 1906 with its main endeavor being in the field of Plumbing and Sanitary Research. A.S.S.E. main office is located in Cleveland, Ohio [21].

The A.S.S.E. has authorized three independent testing laboratories to test products for compliance with the A.S.S.E. Standards mentioned previously in this report. These laboratories are:

(a) The Twining Laboratories, Incorporated,
Fresno, California

(b) The National Sanitation Foundation,
Ann Arbor, Michigan

(c) Factory Mutual Research Corporation,
Norwood, Massachusetts.

When a product is approved in one of these authorized laboratories the A.S.S.E. seal may be displayed on the product. The seal indicates that the product has been certified to be in compliance with the appropriate A.S.S.E. standard as a result of satisfactory laboratory tests. Authorization for the use of the seal is obtained from the Seal Control Board at the A.S.S.E. Central Office.

The seal is issued for a period of five (5) years but must be renewed annually by the manufacturer. The manufacturer must prove to the satisfaction of the Seal Control Board that the product has not been changed or modified in any way that would affect compliance with the requirements under which it was tested. Extension of the seal usage beyond five years may be negotiated with the Seal Control Board. The manufacturer makes all arrangements for testing at an A.S.S.E. approved laboratory and defrays all costs involved. If the manufacturer changes or alters his product without notification, the Board will cancel the manufacturer's right to display the seal.

### 3.4.3 Procedures for a National Voluntarv Laboratory Accreditation Program

During the fall and winter of 1972, R.W. Beausoliel visited five laboratories in expectation that such visits would provide critical information needed to perform an evaluation of each laboratory. We know now that in the half-day alloted for each of the visits, we did not and probably could not have obtained the essential information needed for such evaluations. We know that the business of evaluating laboratories is a complex one, for we have become aware of the work being done by others at NBS to define an acceptable laboratory evaluation program. The evaluation and accreditation program is now established and is presented in detail , with special formatting, in the Appendix, Section 10.3.

Concisely, the ten steps needed to develop a list of accredited laboratories to test backflow prevention devices are as follows:

(1) Some person or organization must request the Secretary of Commerce to find that there is a need for accrediting laboratories to test backflow prevention devices (Sec.7.4(a))

(2) Such request will have to show:
  (a) that standards and test methods exist for the evaluation of backflow prevention devices,
  (b) the number of testing laboratories believed desiring to be accredited to test backflow prevention devices,
  (c) and the number of anticipated users of the testing laboratories service. (Sec. 7.4(b))

(3) Public hearings will be held to provide a forum for any and all opinions to be expressed. (Sec. 7.4(f))

(4) Based on the expressions that come from the hearings, the Secretary of Commerce will either decide to proceed or to withdraw. (Sec. 7.4(g)).

(5) If the Secretary proceeds he will form a National Laboratory Accreditation Criteria Committee for Backflow Prevention Devices. (Sec. 7.4(h)(3)).

(6) The Committee will be directed by the Secretary of Commerce to develop and recommend to him, general and specific criteria to accredit testing laboratories that serve backflow prevention devices. (Sec. 7.6(d)).

(7) When the specific and general criteria have been prepared for the Secretary of Commerce, he will consider them and invite comments from the public. (Sec. 7.8(a))

(8) The input from the hearings will be turned over to the Criteria Committee to evaluate and to advise the Secretary of Commerce (Sec. 7.8(c)).

(9) Should the Secretary of Commerce accept the Criteria Committee's work, the criteria will be accepted and laboratories will be invited to apply for accreditation. (Sec. 7.10(b))

(10) The Secretary of Commerce will report to the public monthly, via the Federal Register, all actions which grant, revoke, terminate, or result in the withdrawal of the accreditation of a laboratory. (Sec. 7.17(c)).

In the above procedures, the initiating action requires that standards and test methods exist for the evaluation of the devices. The A.S.S.E. standards have been submitted to the American National Standards Institute (ANSI) for consideration by the A 112 Committee. For only two of these has the approval process progressed to the stage of final approval.

The correlation of A.S.S.E. standards with the ANSI numbers are:

| | |
|---|---|
| A.S.S.E. 1001 | ANSI A 112.1.1 - 1971 |
| A.S.S.E. 1011 | ANSI A 112.1.3 - 1976 |
| A.S.S.E. 1012 | ANSI A 112.1.4 - |
| A.S.S.E. 1013 | ANSI A 112.1.5 - |
| A.S.S.E. 1015 | ANSI A 112.1.6 - |
| A.S.S.E. 1020 | ANSI A 112.1.7 - 1976 |

Also required to exist for the initiating action is information on the number of testing laboratories desiring to be accredited. To explore the possibility of developing such information, reference was made to the 1976 Directory of the American Council of Independent Laboratories, Inc., 1725 K Street, N.W., Washington, D.C. 20006. (202) 659-3766.

The Directory has a classified index of its membership wherein those laboratories doing qualification testing, hydraulic testing, hydrostatic testing, and also carrying out certification programs are identified by the page number of their advertisement in the directory. All laboratories identified as being in each of the four classifications were selecting for listing here. With the names of the laboratories and three others taken from our files, table 8 was compiled.

Table 8. A List of 24 Independent Testing Laboratories Potentially Interested in Testing Backflow Prevention Devices.(See Sec. 3.4.3)

Applied Research Laboratories of Florida,Inc.
Florida Industrial Research Park SR 27
43650 S.W. 232 Avenue, Dade County,Florida
P.O. Drawer 1,Homestead,Fla. (305) 245-3660

Approved Engineering Test Laboratories,Inc.
15720 Ventura Boulevard, Suite 420
Encino, California 91436
(213) 783-5985

Associated Testing Laboratories, Inc.
9 Brighton Road
Clifton, New Jersey 07012
(201) 473-6455

Bowser - Morner Testing Laboratories,Inc.
420 Davis Avenue P.O. Box 51
Dayton, Ohio 45401
(513) 253-8805

C T L Engineering, Inc.
2860 Fisher Road
Columbus, Ohio 43204
(614) 276-8123

Detroit Testing Laboratory, Inc.
8720 Northend Avenue
Oak Park, Michigan 48237
(313) 398-2100

Electrical Testing Laboratories, Inc.
2 East End Avenue
New York, New York 10021
(212) 288-2600

Engineers Testing Laboratories, Inc.
3737 East Broadway
Phoenix, Arizona 85040
(602) 268-1381

Froehling and Robertson, Inc.
814 West Cary St. P.O. Box 27524 Zip 23261
Richmond, Virginia 23220
(804) 644-3025

General Environments Corp.
6840 Industrial Road
Springfield, Virginia 22151
(703) 354-2000

Arnold Greene Testing Laboratories, Inc.
East Natick Industrial Park
6 Huron Drive, Natick, Mass. 01760
(617) 235-7330

Arnold Greene Testing Laboratories of P.R., Inc.
167 Quisqueya Avenue
Hato Rey, Puerto Rico 00917
(809) 763-3910

Institute for Research, Inc.
8330 Westglen Drive
Houston, Texas 77063
(713) 783-8400

Law Engineering Testing Company
P.O.Box 98008, 2000 Century Parkway
Atlanta, Georgia 30329
(404) 325-3933

Shilstone Engineering Testing Laboratory, Inc.
1714 Memorial Drive
Houston, Texas 77007
(713) 224-2047

Skinner and Sherman, Inc.
227 California Street
Newton, Massachussetts 02195
(617) 332-8300

Smith - Emery Company
781 East Washington Boulevard
Los Angeles, California 90021
(213) 749-3411

Southwestern Laboratories,
222 Cavalcade Blvd. P.O. Box 8768
Houston, Texas 77009
(713) 692-9151

Testing Consultants, Inc.
525 East Mississippi Avenue
Denver, Colorado 80210
(303) 777-1771

Twining Laboratories of Southern California, Inc.
3310 Airport Way P.O. Box 47
Long Beach, California 90801
(213) 426-3355

United States Testing Company, Inc.
1415 Park Avenue
Hoboken, New Jersey 07030
(201) 792-2400

Value Engineering Laboratory
2550 Huntington Avenue
Alexandria, Virginia 22303
(703) 960-4600

Wingerter Laboratories, Inc.
1820 N.E. 144th Street Drawer L
North Miami, Florida, 33161
(305) 944-3401

York Research Corporation
One Research Drive
Stamford, Connecticut 06904
(203) 325-1371

## 3.5 A Conceptual Model Cross-Connection Control Program

In recent months a conceptual model for a realistic cross-connection control program has been evolving. The necessary elements are even now developing, with a minimum of input from the authors. The model is shown as figure 4.

I. In the model, credit is given to EPA as being the source of activity needed to bring all elements together into a workable program. The line of action indicates that EPA would provide guidelines to state or municipal authorities who would in turn develop the appropriate legislation or ordinance to establish the cross-connection control program.

II. The enabling laws will require funds for the operation of the program. The funding would pay for two activities:

(a) An inspection program that:
  1. Authorized installation of particular backflow prevention devices where needed.
  2. Inspected the installation of the device at time of construction.
  3. Carried out a regular schedule of reinspection and testing to determine that backflow protection devices were performing adequately.

(b) A contractual arrangement with an independent testing laboratory to:
  1. Audit or monitor the cross-connection control program on a annual or semi-annual basis to assure that the program was being carried out under (a) above as required by law, and
  2. To provide technical guidance and training to the inspection staff as needed and as contracted for.

III. To be qualified to make decisions or judgments on suitable backflow protection devices the inspection staff will need technical guidance for the approval of devices. Such guidance could come from:
  1. Knowledge that suitable devices are available in a competitive market to fill needs in most applications.
  2. Knowledge of existence of nationally recognized product standards that assure quality and dependability for the several types of devices.
  3. Knowledge of the existance of a certification program that verifies on a continuing basis that devices claiming to meet the requirement of the standards actually do so.

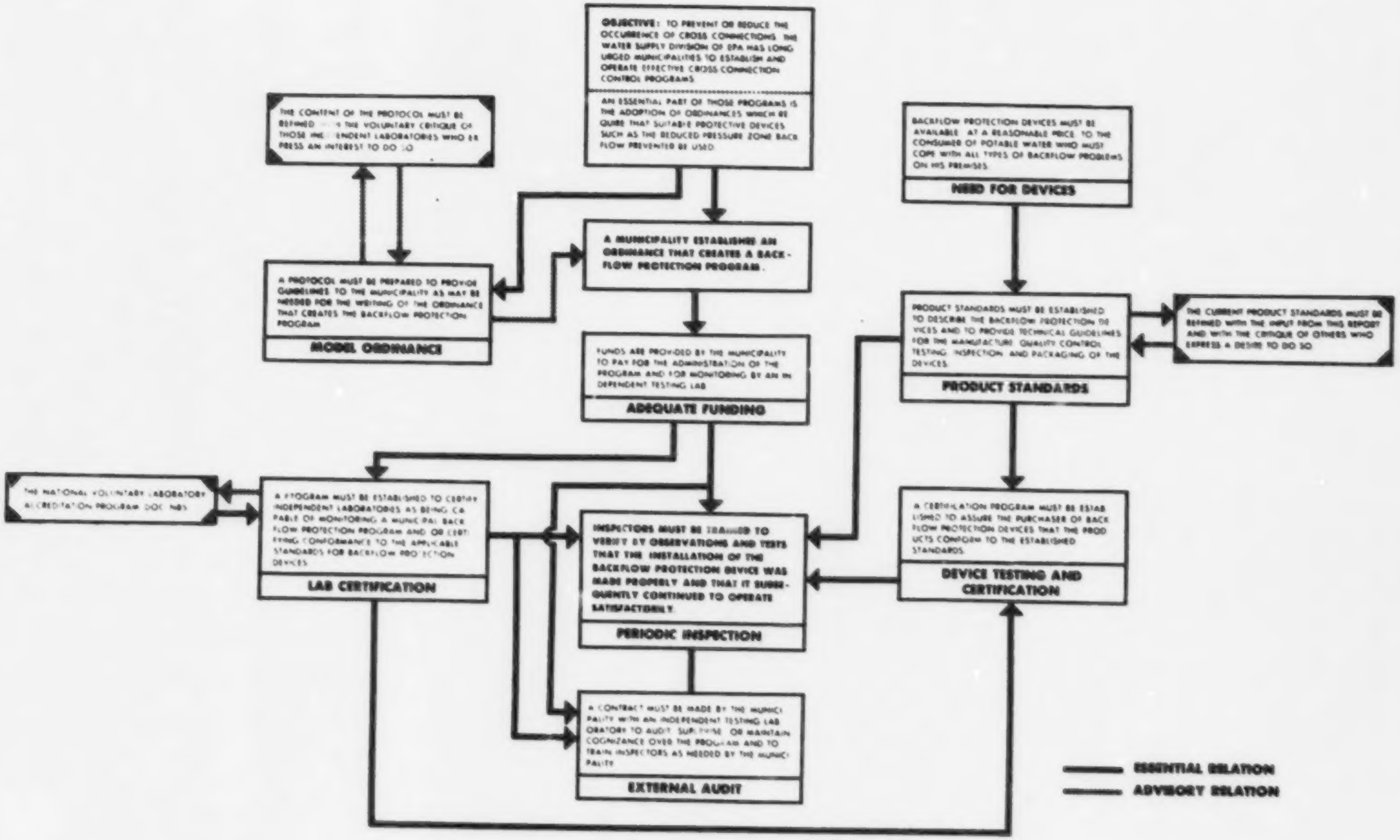

THE CONTENT OF THE PROTOCOL MUST BE REFINED WITH THE VOLUNTARY CRITIQUE OF THOSE INDEPENDENT LABORATORIES WHO EXPRESS AN INTEREST TO DO SO
OBJECTIVE: TO PREVENT OR REDUCE THE OCCURRENCE OF CROSS CONNECTIONS. THE WATER SUPPLY DIVISION OF EPA HAS LONG URGED MUNICIPALITIES TO ESTABLISH AND OPERATE EFFECTIVE CROSS-CONNECTION CONTROL PROGRAMS.
AN ESSENTIAL PART OF THOSE PROGRAMS IS THE ADOPTION OF ORDINANCES WHICH REQUIRE THAT SUITABLE PROTECTIVE DEVICES SUCH AS THE REDUCED PRESSURE ZONE BACKFLOW PREVENTER BE USED.
BACKFLOW PROTECTION DEVICES MUST BE AVAILABLE AT A REASONABLE PRICE TO THE CONSUMER OF POTABLE WATER WHO MUST COPE WITH ALL TYPES OF BACKFLOW PROBLEMS ON HIS PREMISES.
NEED FOR DEVICES
A MUNICIPALITY ESTABLISHES AN ORDINANCE THAT CREATES A BACKFLOW PROTECTION PROGRAM.
A PROTOCOL MUST BE PREPARED TO PROVIDE GUIDELINES TO THE MUNICIPALITY AS MAY BE NEEDED FOR THE WRITING OF THE ORDINANCE THAT CREATES THE BACKFLOW PROTECTION PROGRAM
MODEL ORDINANCE
PRODUCT STANDARDS MUST BE ESTABLISHED TO DESCRIBE THE BACKFLOW PROTECTION DEVICES AND TO PROVIDE TECHNICAL GUIDELINES FOR THE MANUFACTURE, QUALITY CONTROL, TESTING, INSPECTION, AND PACKAGING OF THE DEVICES.
PRODUCT STANDARDS
THE CURRENT PRODUCT STANDARDS MUST BE REFINED WITH THE INPUT FROM THIS REPORT AND WITH THE CRITIQUE OF OTHERS WHO EXPRESS A DESIRE TO DO SO
FUNDS ARE PROVIDED BY THE MUNICIPALITY TO PAY FOR THE ADMINISTRATION OF THE PROGRAM AND FOR MONITORING BY AN INDEPENDENT TESTING LAB
ADEQUATE FUNDING
THE NATIONAL VOLUNTARY LABORATORY ACCREDITATION PROGRAM DOC NBS
A PROGRAM MUST BE ESTABLISHED TO CERTIFY INDEPENDENT LABORATORIES AS BEING CAPABLE OF MONITORING A MUNICIPAL BACKFLOW PROTECTION PROGRAM AND OR CERTIFYING CONFORMANCE TO THE APPLICABLE STANDARDS FOR BACKFLOW PROTECTION DEVICES
LAB CERTIFICATION
INSPECTORS MUST BE TRAINED TO VERIFY BY OBSERVATIONS AND TESTS THAT THE INSTALLATION OF THE BACKFLOW PROTECTION DEVICE WAS MADE PROPERLY AND THAT IT SUBSEQUENTLY CONTINUED TO OPERATE SATISFACTORILY.
PERIODIC INSPECTION
A CERTIFICATION PROGRAM MUST BE ESTABLISHED TO ASSURE THE PURCHASER OF BACKFLOW PROTECTION DEVICES THAT THE PRODUCTS CONFORM TO THE ESTABLISHED STANDARDS.
DEVICE TESTING AND CERTIFICATION
A CONTRACT MUST BE MADE BY THE MUNICIPALITY WITH AN INDEPENDENT TESTING LABORATORY TO AUDIT, SUPERVISE, OR MAINTAIN COGNIZANCE OVER THE PROGRAM AND TO TRAIN INSPECTORS AS NEEDED BY THE MUNICIPALITY
EXTERNAL AUDIT
ESSENTIAL RELATION
ADVISORY RELATION

Figure 4. A Model Defining Essential Elements of a Backflow Protection Program

IV. The existence of a competitive market depends upon a demand for the devices. The demand may be expected to increase as the number of cross-connection control programs increase. The demand could then be expected to motivate new designs - utilizing new materials - and necessitating evaluation of the new products.

V. The product standards currently in existence need to be improved from the present stage to assure that testing and certification may be carried out uniformly by any certified independent testing laboratory. To provide for approval of suitable innovative devices, the requirements for backflow protection devices need to be stated in performance language. Another document of NBS, NBSIR 76-1020 "Guide Criteria for Laboratory Evaluation of Backflow Prevention Devices for Protection of Potable Water Supplies" by Grover C. Sherlin, Robert W. Beausoliel, and Lawrence S. Galowin will aid in the develop of the performance language.

VI. Certification of the backflow protection devices would be carried out by authorized independent testing laboratories who receive compensation for such certification from the manufacturers. Authorization of the certifying laboratories could be accomplished through the U.S. Department of Commerce Accreditation Program.

VII. The National Voluntary Laboratory Accreditation Program is now available to accredit testing laboratories to test backflow prevention devices. In Section 3.4.3 a concise listing is given of steps required to initiate the program. The complete program is presented as Appendix Section 10.3.

# 4.0 EVALUATION OF DEVICES

## 4.1 Design Considerations that Affect Reliability

### 4.1.1 Air Gaps

The design of air gaps in a potable water distribution line depends upon the size of the effective opening and the distance between the supply fitting outlet (spout or faucet) and a near-by wall. Above one-inch diameter of effective opening the length of air gap is specified to be twice the diameter; except when affected by a near-by wall it is to be three times the diameter. See figure 3.

The primary function of the air gap may be defeated by attaching a hose, a pipe, or a tube between the potable water outlet and a non-potable source. Possible means to prevent such practices are by designing or modifying outlets of faucets to discourage the attachment of hoses and by initiating educational programs to apprise the public that attachment of such hoses can create potential health hazards.

### 4.1.2 Barometric Loops

The Environmental Services Branch, National Institutes of Health, in cooperation with the Division of Environmental Health and Safety, University of Minnesota Health Service investigated the barometric loop [27]. The investigation showed that air bubbles could transfer contaminated water through the loop when back-siphonage occurred. They developed an air-water separator that proved effective in preventing such transfer. Additional studies were recommended to determine the effect diffusion might have in the transfer of contaminants through the loop. There are no data on how widely barometric loops are used or on how many loops are used with air-separators. The use of the separators with loops does not appear in the model plumbing codes.

### 4.1.3 Pipe Applied Vacuum Breakers

The pressure type vacuum breakers (PVB) and the atmospheric type vacuum breakers (AVB) are vulnerable to air port blockage by rags, etc. Such blockage would render the device ineffective. Suggested countermeasures are educational efforts to explain the need to keep the air ports or air inlets of the vacuum breakers open, and frequent periodic inspection, test and repair. Although PVB has means for testing the device in line, standards do not require similar test arrangement for AVB.

### 4.1.4 Hose Connection Vacuum Breakers

There are two types of hose connection vacuum breakers (HCVB). One type has a diaphragm to seal the air inlets but does not have a check valve to seal the water inlet. This type of HCVB is essentially a special design of AVB which is not intended to be subjected to back pressure. The other type of HCVB has both a diaphragm and check valve. For such devices a nationally recognized standard ASSE 1011 specifies the following test requirements which are unique for vacuum breakers:

- The outlet of the device is subjected to a back pressure created by a ten-foot column of water within an elevated garden hose. Backflow through the check must not take place under this pressure.

- Leakage of water from the hose through the HCVB at the rate of 1/4-pint per minute is permitted to flow through the vent ports to the ambient in order to relieve back pressure caused by the column of water in the hose. (The check valve prevents backflow into the inlet of the device when the water is discharged from the vent ports).

The objectives of these two tests conflict with the principles set forth by two authorities concerned with vacuum breakers. For instance, the following attitudes were found concerning the first and second test methods respectively:

- HCVB exposure to back pressure is not allowed under AWWA's Pacific Northwest Sections Manual [1]. The Manual depicts this HCVB (with the check valve) as an AVB which the manual states is not effective against backflow due to back pressure.

- Dawson and Kalinske have said that the air inlets of vacuum breakers should not be used to convey water as lime deposits may cause closure of the air inlets. Also the air inlets should not be placed where they would get exposed to polluted water [3].

A third test method concerns the fouling of the check with a wire (a common test for vacuum breakers) [20] to simulate check valve leakage resulting from check material failure or a foreign substance lodged between the check and its seat. The test is summarized as follows:

- The back-siphonage test with vacuum applied at the inlet to HCVB requires the check to be fouled.

- In the back pressure portion of the test method, the check valve is not fouled. (The standard does not say that backflow will occur if the check leaks).

It seems reasonable that if the device effectively prevents backflow under back-siphonage conditions with a fouled check, the device should also effectively prevent backflow due to combined back-siphonage and back pressure because the standard indicates that the device effectively relieves back pressure. The standard does not consider the simultaneous application of both vacuum at the inlet and back pressure at the outlet. Such likely conditions could occur when filling a back yard swimming pool with an elevated garden hose. Because the standard test methods did not address this likely condition, a simple test, as explained in Appendix Section 10.4, was carried out to see how effective the device would be in relieving back pressure and preventing backflow with the simultaneous application of vacuum at the inlet and back pressure at the outlet with the check fouled in the manner of the standard test method. Backflow occurred at 0.2 gpm. The test results indicate that backflow remained constant with increasing elevation of the terminal end of the hose (increasing back pressure). Such a constant backflow rate into the inlet of the device does indicate that the device is effective in relieving back pressure. However, the results also indicate that a tight check valve is required to prevent backflow under these conditions. It would seem reasonable that the standard consider this limitation of the device.

It appears that the HCVB which includes the check valve is superior to the type that does not have a check valve. The use of garden hoses with HCVB naturally subjects HCVB to back pressure. The HCVB without a check valve can not resist back pressure. A simple test by the National Bureau of Standards in accordance to ASSE 1011 [21] showed that the device would backflow when subjected to atmospheric pressure at the inlet and a three-foot head of water at the outlet. Because of this, NBS believes that HCVB without a check should not be used with garden hoses. It is possible to overly criticize this relatively inexpensive device (present cost about four dollars) because obviously a garden hose installation is safer with HCVB than without it. Alternatives to present HCVB installation for garden hose applications could be the use of the pressure vacuum breaker in the hose supply or, perhaps, a redesign of the water supply piping such that the terminal end of a garden hose under normal use would not be elevated above HCVB or other vacuum breaker. Such approaches would tend to increase the cost of the installation; but it must be remembered, however, that garden hose installation can cause deaths as shown by the example in section 2.1 of this report and the best protection must be provided. It may be that HCVB is quite adequate if the check valve does not leak. A study should be carried out to determine the following:

- Will the air ports of the HCVB become blocked with lime deposits as mentioned by Dawson and Kalinske [3]?
- Is there, in reality, a high risk of contamination at the air ports of HCVB with the check valve?6/
- How reliable is the check valve under service conditions?
- Would the HCVB give additional protection if it were installed at the nozzle end of the garden hose or at both the faucet end and nozzle end?

With any such change(s), the manufacturers and/or administrative authorities should make the general public aware of the importance and function of HCVB and other devices (perhaps TV coverage from time to time and informative literature concerning backflow potential included with the water purveyors bills).

### 4.1.5 Double Check Valve Assemblies

The double check valve assembly (DCVA) gives no visual indication of check-valve failure. Protection depends entirely on tight check valves. Good preventive maintenance will tend to preclude check-valve leakage.

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6/ It is interesting to note that if a 50-foot length of 1/2-inch diameter garden hose was used to fill an elevated swimming pool such that water would backflow from the hose through the vent ports to the surrounding atmosphere at the rate allowed in the standard, 1/4-pint per minute (approximately 29 cubic inches per minute), all of the water in the hose (about 118 cubic inches) would flow through the ports in about five minutes. At the end of this time, possibly non-potable swimming pool water would be flowing in the hose and vent ports.

### 4.1.6 Backflow Preventers with Intermediate Atmospheric Vent

Since the backflow preventers with intermediate atmospheric vent are relatively new, no feedback from installation experience was found.

### 4.1.7 Reduced-Pressure Principle Back Pressure Backflow Preventers

Some authorities declare that a reduced-pressure principle backflow preventer (RPBD) will permit backflow when its upstream and downstream check valves both leak when there is vacuum at the inlet and back pressure at the outlet. In light of such statements, and in view of the fact that existing standards for RPBD do not have tests for back-siphonage, a limited NBS laboratory test of a 3/4-inch device was conducted to determine if it would permit backflow. See Appendix 10.5 for details. With the check valves fouled with 0.042-in diameter wires in the manner normal during vacuum breaker tests [20], with a vacuum of 11 centimeters of mercury absolute (about 25 inches of mercury gage) at the inlet, and with low back pressure of 1.31 psig, and zone pressure of one inch of water column gage, an average backflow rate of 0.029 gpm into the inlet of the device occurred. The relief valve was open under these conditions and discharged water from the zone to drain at only 1.85 gpm indicating that the zone was not overloaded (this rate was well below the 5 gpm allowed by the standards). It was noted that the soft rubber check valve material used in the upstream check of this particular model of RPBD tended to slowly seat around the wire thus preventing backflow into the inlet.

The results above are in agreement with those for a similar test of a 3/4-inch RPBD made at NBS over 20 years ago.7/ During that test the check valves of RPBD were fouled with 0.027-inch diameter wire. The supply piping to the device was subjected to vacuum up to 18-inches of mercury gage, and at the same time a positive water pressure of 25 psig was maintained in the piping downstream of the device. The final paragraph concerning the test results stated the following: "In none of the vacuum tests described above was there any indication whatsoever of backflow. Apparently the resilient nature of the main valve seat and the force of the spring, which aids in closing the valve, are responsible, at least in part, for good results obtained. Even when the piece of wire

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7/ National Bureau of Standards Report on Test of Backflow Preventer Requested by the Federal Security Agency, National Institutes of Health, U. S. Public Health Service, Washington, D. C. on January 31, 1952. Prepared by R. S. Wyly.

was placed between the main valve and its seat, there was no apparent backflow of either air or water. Inspection of the valve showed that the wire had merely been pressed into the valve seat, and when the unit was disassembeled, the wire fell out, leaving only an insignificant mark on the valve seat." The final conclusion of the report states. "It is obvious that under extreme conditions, backflow could take place in the unit tested; for example, with the check valve and the main valve very poorly seated or held open, simultaneously with a high vacuum in the supply line. However, no backflow preventer or vacuum breaker known at this time is entirely perfect or foolproof. It is believed that in the great majority of cases serious imperfections in valve seating will develop gradually; hence, in the device tested, visual evidence of this fact would be at hand long before any real danger of backflow exists."

There appear to be four reasons for backflow during the test presented in Appendix Section 10.5

( i) The fouling wires used were 0.042-inches in diameter versus 0.027-inches in diameter for the earlier NBS test. The smaller diameter would favor check valve seating into the soft check material.

( ii) A vacuum of 11-centimeters of mercury absolute was used in this work (about 25-inches of mercury gage) which is somewhat more severe than the 18 inches of mercury gage used in the earlier NBS test.

(iii) The device used in this work was installed in a vertical line (as sanctioned by the manufacturer) with the direction of normal flow "Down". The older device was installed in a horizontal line.

( iv) There were differences in manufactures designs, i.e., internal shape and size of the zone, discharge port, etc.

It seems likely, that had the 0.042-inch diameter fouling wire been used during the earlier test, backflow probably would have occurred. It must be said also that the rate of backflow occurring during the test presented in Appendix 10.5 was very low. The likelihood of such fouling of the device is probably remote because the manufacturer requires the use of a strainer upstream of the device and the upstream check valve has two seats that have to be fouled simultaneously. Considerable difficulty was experienced during initial efforts to get the wire to remain in position across both seats simultaneously.

Additional tests should be carried out concerning RPBD of other sizes and from other manufacturers. Preliminary information obtained from such tests would be of value in the development of a back-siphonage test for a RPBD. The present standards for RPBD do not have back-siphonage test methods or requirements; however, the device is relied upon by many users to give effective protection against back-siphonage.

It was beyond the scope and resources of this project to determine the probability of the two check valves of an RPBD leaking simultaneously or whether any RPBD of other manufacturers would allow backflow or whether the size or configuration of the device contributed to the backflow failures. An attempt was made to get information from the Los Angeles Department of Water and Power (DWP) concerning the number of times in any one year period on an average that RPBD experiences the failure of both check valves. DWP has computer records of inspection, test, and performance data on over 3,000 backflow preventers [11]; however, a computer program would have to be developed to retrieve this information. The Department of Public Utilities, City of Tacoma, Washington provided data for yearly tests conducted on RPBD and double check valve assemblies (DCVA) for the past 2 1/2 years. Data collected from 114 RPBD tests showed several failures of the RPBD relief valves; however, only one RPBD was found to have both check valves leaking simultaneously. This condition occurred because of debris under the checks. Only two DCVA were found to have both checks leaking simultaneously out of 59 tests of DCVA conducted during that period. Factory Mutual Fire Insurance Companies inspected 1,032 sets of DCVA and only four sets were found out of this number to have both checks leaking simultaneously [34]. The use of strainers ahead of RPBD may be a precaution to reduce risk of check leakage due to debris. ASSE Standard 1013 for RPBD recommends the use of strainers but other standards do not. It is believed by some that strainers introduce excessive pressure drop.

The U. S. Navy has reported that on certain docks and piers the relief valves of RPBD have frozen. Such failures have become an expensive and not completely solved problem [11]. Repiping for installation of a RPBD within a heated space could be a solution.

## 4.2 Assessment of Standard Test Methods

In this section the test methods given in standards for the backflow prevention devices will be evaluated against the following criteria:

(a) Understandable, Usable and Fair: Can any normally equipped laboratory perform the tests as described in the standard? Can innovative devices be accepted under the test method described or would such devices be restricted from approval?

(b) Methods that test appropriate attributes (life cycle phenomena): Are the test methods realistic? Do they expose devices to water supply conditions of temperature, pressure, flow, chemistry, water borne inclusions, and actual or test contaminants that could pollute the potable water?

(c) Repeatability and Accuracy: Are the test data repeatable and how many runs of test data are taken? How accurate are the measured data?

(d) Limit testing, Failure Modes, Maintainability, and Field Testing: Are tests used to determine common modes of device failure? Is level of maintenance determined? Do laboratory tests assure satisfactory field performance?

(e) Cost/effectiveness: Are test methods periodically reviewed to determine if instrumentation techniques or other newly developed techniques might substantially reduce the cost of testing and improve data quality?

By the formulation of these criteria there has been established a "yard stick" against which the test methods may be evaluated. In tables 9, 10 and 11 the tests methods are summarized with comments as appropriate. In the following subsections the tests methods will be discussed in terms of the above criteria.

In Appendix 10.6 each of the ASSE Standards have been analysed in great detail to identify the test requirements, test setup and preparation for testing, test procedure, observations records and computations and basis for rejection of device. The matrix format used facilitates the identification of missing elements.

### 4.2.1 Understandable, Usable, and Fair Test Methods

The ASSE Standards have test setups and test methods for a laboratory to follow which are understandable and usable. The FCCCHR and IAPMO Standards imply identical hydraulic laboratory tests but

Table 9 Summary of Test Methods Found in Current Standards for Atmospheric Types of Backflow Preventers - with Comments

| Devices and Standards | Test Methods | Comments |
|---|---|---|
| Air Gap (AG)<br>ANSI A112.1.2 1973 [26] | ° Measurement of the length of the air gap between the flood level rim of a plumbing fixture or tank and the effective (minimum) diameter of the water supply outlet | Adequate test methods |
| Atmospheric Vacuum Breaker (AVB)<br>A.S.S.E. 1001,1970<br>ANSI A112.1.1 1971 [20] | ° Nontoxic certification<br>° Positive pressure test<br>° Air port shield examination<br>° Air flow test<br>° Water rise test | Test methods are indirect, that is, a tracer,yielding quantitative results is not used to simulate contaminants. |
| Antisiphon Flush Valve Ball Cock (AFVBC)<br>A.S.S.E. 1002,1968 [30] | ° General requirements<br>° Vacuum breaker equipped<br>° Air gap equipped ball cock | |
| Barometric Loop (BL) | (No test methods) | This device has features which may be engineered into the installation to make it reliable and cost-effective. |
| Backflow Preventers with Intermediate Atmospheric Vent (BPIA)<br>A.S.S.E. 1012,1972 [22]<br>ANSI A112.1.4 - 1976 | ° Noise<br>° Hydrostatic test - total<br>° Hydrostatic test - check valve<br>° Tightness of downstream check<br>° Tightness of inlet check<br>° Atmospheric vent valve leakage<br>° Backflow through inlet check<br>° Atmospheric vent,opening pressure<br>° Back-siphonage<br>° Flow and pressure loss<br>° Flow with low supply pressure | The standard does not have a test method to cover the likely condition of simultaneous vacuum at the inlet and back pressure at the outlet<br>A tracer to simulate contamination could be used to give quantitative measurements of check valve leakage. The colored water tracer called for can give only a qualitative value. |
| Hose Connection Vacuum Breakers (HCVB)<br>A.S.S.E. 1011,1970 [21]<br>ANSI A112.1.3 - 1976 | ° Resistance to hydrostatic test<br>° Noise<br>° Water flow capacity<br>° Leakage from vent ports<br>° Water hammer shock resistance<br>° Backflow due to back pressure<br>° Backflow due to back-siphonage<br>° Resistance to bending<br>° Ability to resist and relieve back pressure<br>° Deterioration in hot and cold water. | Although the test method for backflow, section 2.1.6,requires the use of a colored water tracer, this is a qualitative test only which depends on visual ability to detect the presence of the tracer. A measureable tracer is not used. |

Table 10 Summary of Test Methods Found in Current Standards for Double Check Valve Assemblies and for Pressure Type Vacuum Breakers - with Comments

| Devices and Standards | Test Methods | Comments |
|---|---|---|
| Double Check Valve Assembly (DCVA)<br>A.S.S.E. 1015,1972 [24]<br>ANSI A112.1.6 - 1976 | ° Hydrostatic test - full<br>° Hydrostatic back pressure test of check valves<br>° Tightness of check valves against upstream pressure of 1 psi.<br>° Rated flow and pressure loss | Lacks realistic test for performance under back-siphonage conditions, i.e., vacuum is not applied to the inlet of the device. |
| Double Check Valve Assembly (DCVA)<br>FCCCHR - 1974 [29]<br>IAPMO PS 31-74 [28]<br>AWWA C506 - 69 [31] | ° Specifies similar requirements as in A.S.S.E. 1015<br>° Also specifies but without a test procedure:<br>- shock and water hammer<br>- hydrostatic test on all barriers<br>- 12 months field performance<br>- no backflow under all conditions of pressure differential<br>- tolerance to sand, scale and other interfering materials<br>- devices for elevated temperatures to be so tested | The FCCCHR and IAPMO test requirements are very similar. The AWWA is less developed.<br>Test requirments must have test procedures to be useful broadly<br>Periodic testing of devices in a cross-connection control program may economically substitute for field testing. |
| Antisiphon Pressure Type Vacuum Breakers (PVB)<br>A.S.S.E. 1020,1974 [25]<br>ANSI A112.1.7 - 1976 | ° Hydrostatic test,internal,total<br>° Hydrostatic test, check valve back pressure<br>° Check valve force loading<br>° Atmospheric vent, opening pressure<br>° Air passageway areas<br>° Back-siphonage prevention<br>° Rated flow and allowable pressure loss | Test methods are indirect, that is, a tracer,yielding quantitative results, is not used to simulate contaminants. |
| Pressure Type Vacuum Breaker Assemblies (PVB)<br>FCCCHR - 1974 [29]<br>IAPMO PS 31-74 [28] | ° Specifies similar requirements as in A.S.S.E. 1020<br>° Also specifies but without a test procedure:<br>- shock and water hammer<br>- hydrostatic test on all barriers<br>- 12 months field performance<br>- tolerance to sand,scale and other interfering materials<br>- devices for elevated temperatures to be so tested | The FCCCHR and IAPMO test requirements are very similar. IAPMO definitely single and double check valve types. FCCCHR (?)<br>Test requirements must have test procedures to be useful broadly.<br>Periodic testing of devices in a cross-connection control program may economically substitute for field testing. |

Table 11 Summary of Test Methods Found in Current Standards for Reduced Pressure Principle Back Pressure Backflow Prevention Devices - with Comments

| Devices and Standards | Test Methods | Comments |
|---|---|---|
| Reduced Pressure Principle Backflow Prevention Device (RPBD)<br>A.S.S.E. 1013,1971 [23]<br>ANSI A112.1.5 - 1976 | ° Hydrostatic test - full<br>° Hydrostatic test - outlet only<br>° Outlet check valve, drip tightness<br>° Rated flow and allowable pressure loss<br>° Zone pressure versus inlet pressure (flowing status)<br>° Zone pressure versus inlet pressure (static status)<br>° Relief discharge rate (backflow condition)<br>° Relief valve opening and closing<br>° Relief valve discharge versus inlet pressure surge | Lacks realistic test for performance under back-siphonage conditions, i.e., vacuum is not applied to the inlet of the device.<br>Does not require a field evaluation after the device has passed the laboratory tests.<br>Test methods are indirect, that is, a tracer yielding quantitative results is not used to simulate contaminants. |
| Reduced Pressure Principle Backflow Prevention Device (RPBD)<br>FCCCHR - 1974 [29]<br>IAPMO PS 31-74 [28]<br>AWWA C506-69 [31] | ° Specifies similar requirements as in A.S.S.E. 1013<br>° Also specifies but without a test procedure:<br>- shock and water hammer<br>- hydrostatic test on all barriers<br>- 12 months field performance<br>- no backflow under all conditions of pressure differential<br>- tolerance to sand,scale and other interfering materials<br>- devices for elevated temperatures to be so tested | The FCCCHR and IAPMO test requirements are very similar. The AWWA is less developed.<br>Test requirements must have test procedures to be useful broadly.<br>Periodic testing of devices in a cross-connection control program may economically substitute for field testing. |

they do not give test methods. Field test setups and field test methods are given by FCCCHR and IAPMO, but these are not clear concerning test site selection. ASSE Standards do not require a field test but do invite the manufacturers to furnish recommendations for field testing upon request. The field test appears to be a major difference between requirements of some standards. The field test is an aspect of backflow preventer testing that requires further study.

The standards are for particular product types and are generally prescriptive concerning functional parts. The standards do not have a mechanism that would allow test of an innovative device that may be entirely different than the particular products covered which makes those standards difficult if not impossible to apply to innovative devices.

### 4.2.2 Methods that Test Appropriate Attributes

#### 4.2.2.1 Backflow Prevention

Although authorities claim the RPBD and DCVA prevent back-siphonage, the standards for RPBD and DCVA do not have back-siphonage requirements or back-siphonage test methods. No standard test requires that vacuum be applied to the inlet of RPBD and DCVA. The standards do not give emphasis to the ability of RPBD to prevent backflow due to back-siphonage. In fact, the opposite impression is given. The foreword to ASSE 1013 for RPBD states the following: "This standard covers only the type of device which is identified as a Reduced-Pressure Principle Backflow Preventer which is designed primarily for the prevention of backflow due to back pressure." (Underline added for emphasis).

ASSE 1012, Backflow Preventers with Intermediate Atmospheric Vent, requires a back-siphonage test for the very inexpensive device, about $17.00, as compared to RPBD which would cost several hundred dollars. This device has two independently operating check valves separated by an intermediate chamber with provision for automatically venting it to the atmosphere. Therefore, although it does not incorporate a relief valve, it is similar to RPBD in configuration. ASSE standard 1012 has a test method to determine that no back-siphonage will occur if both check valves leak when vacuum is applied to the inlet of BPIA and the downstream pressure is atmospheric. (A basic purpose of this device is to protect the potable water supply against backflow where contaminants located within the outlet piping are under pressure from such equipment as a low pressure residential heating boiler). In light of the fact that back pressure will exist continuously during normal operation of the device, it would seem that the above mentioned back-siphonage test method would be more realistic if it were performed with back pressure on the downstream side in lieu of atmospheric pressure.

The test method concerning HCVB was discussed in section 4.1.4. The basic conclusion concerning HCVB (without check valves) is that it would not pass the backflow test of HCVB (with check valves); consequently, it would not be approved under ASSE 1011 test methods. The device is a special AVB that should as a minimum be tested under the procedures of ASSE 1001. The test methods for HCVB (with check valve) concerning backflow due to back-siphonage and back pressure appear adequate. However, the tests would be more realistic if a quantitative tracer could be used that relates to insecticides, herbicides, car wash soap, swimming pool water and perhaps other substances that are associated with garden hose application.

The water rise test for AVB and PVB appears to be generally effective but could be improved upon if a quantitative tracer could be used that relates to sewage and other commonplace contaminants. The ASSE Standards do not apply the water rise test to AVB, HCVB or BPIA when the devices are at operating temperatures. IAPMO has no such test for PVB. It seems reasonable that moving parts of devices might bind due to material expansion or contraction which could cause device malfunction.

Additional backflow test improvements concerning all devices would encompass tests that show the device to meet all of the operating requirements. These are as follows:

- Functional operation under dynamic conditions.
- Functional operation at design pressure temperature combinations.
- Functional operation would, of course, be under exposure to vacuum at the inlet, pressure at the outlet and combinations of vacuum and back pressure.

Generally standards for devices do not test the devices for failure modes. RPBD failure is generally indicated by water flowing from the zone. However, the device does not have a means to warn of failure unless someone actually sees the water discharging from the zone. A remote-indicating device for RPBD located in hazardous areas such as sewage treatment plants would be an improvement. No standard for other devices considers failure detection.

### 4.2.2.2 Nontoxic Materials

Devices should be constructed of nontoxic materials. ASSE Standards are the only standard that consider nontoxic materials. However, ASSE looks for a statement from the manufacturers that all materials in contact with the potable water are nontoxic. No criteria such as that given in the U. S. Public Health Service Drinking Water Standards [8] is mentioned. No standard cites a test method for this important parameter. FCCCHR, IAPMO, and AWWA Standards do not have requirements concerning toxicity of materials. The standards should address this aspect of devices definitively because one of the most important attribute of devices is nontoxicity.

### 4.2.2.3 Design Temperature

The standards are not consistent concerning test methods at design temperatures. For instance, ASSE has design temperature tests for AVB but no design temperature tests for RPBD and DCVA. On the other hand, FCCCHR and IAPMO have tests for RPBD and DCVA if the design temperature exceeds 110°F. Such tests are important for all devices because of possible binding of moving parts at elevated operating temperatures. It seems reasonable that standards should not be inconsistent concerning temperature tests.

### 4.2.2.4 Rated Flow and Allowable Pressure Loss and Hydrostatic Pressure Resistance

The standards (ASSE, AWWA, FCCCHR and IAPMO) agree on the acceptable flow rates for RPBD and DCVA. ASSE test methods for pressure drop versus flow rate are defined and appear adequate. AWWA does not have test methods, FCCCHR and IAPMO have implied tests but their methods are not defined. ASSE has acceptable flow rate and allowable pressure loss test methods for all devices except AVB. It would seem reasonable that acceptable flow rates and an acceptable test method be given for AVB.

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[8] Under the Safe Drinking Water Act, Public Law 93-523, National Interim Primary Drinking Water Regulations were promulgated December 24, 1975 to become effective 18 months later.

ASSE, FCCCHR, and IAPMO have hydrostatic pressure tests for devices. However, there is some inconsistency in the duration of the time that internal pressure of two times working pressure (2 x 150 psig) is applied. FCCCHR and IAPMO require at least two minutes. ASSE requires a ten minute application. The basic purpose of this test is to observe any leaks in valve bodies and check valves or distortion of parts. The test time should be standardized. ASSE requires that AVB be subjected to a hydrostatic test at design temperature extremes (32°F and 212°F for hot water devices and 32°F and 110°F for cold water devices) but other devices such as RPBD which has identical operating requirements is not tested at a design temperature.

#### 4.2.2.5 Water Hammer

The standards are inconsistent concerning test methods for water hammer. ASSE has water hammer tests for HCVB but no tests for RPBD and DCVA. FCCCHR and IAPMO indicate water hammer tests but do not give the methods for RPBD and DCVA.

Water hammer results in overpressure that could occur periodically. In light of this, devices should be exposed to a certain number of cycles of water hammer to determine possible failure of parts. A similar test method is used on shock absorbers that prevent water hammer. This test method is detailed in the standard for water hammer arresters [35].

#### 4.2.2.6 Noise

ASSE has a noise test method for HCVB and BPIA but does not mention a test for RPBD and DCVA. The method basically depends on the hearing ability of the test personnel. FCCCHR considers that RPBD and DCVA should not "chatter" which implies noise but no test method is given. It is important that these devices not be noisy. Users may defeat them or have them removed from service. Study would be required to develop quantitative techniques to detect noisy devices.

#### 4.2.2.7 Resistance to Actual Contaminants or Simulated Contaminants Under Laboratory Conditions

No standard test method requires that contaminants such as sewage or other toxic substance or an appropriate nontoxic tracer be used to demonstrate quantitatively the ability of the devices to prevent backflow of contaminants under realistic conditions. For example, such performance standard should include a tracer test for functional performance under various steady state normal flow, and dynamic flow conditions (water hammer, etc.).

**Although the standards for devices do not consider these realistic conditions, such tests have been performed on one model of RPBD by the Oak Ridge National Laboratory (ORNL) using the procedures of activation analysis [36]. The RPBD passed this test which had a sensitivity of about 0.2 parts per billion of manganese. The nonradioactive test was generally as follows:**

(a) The water supply at the test setup was first sampled to determine the threshold level of manganese, if any.

(b) The manganese tracer was introduced down stream of the device and the device subjected to pressure differentials, fluctations water hammer, etc.

(c) The upstream side of the device was next sampled to determine if manganese had backflowed. The samples were irradiated in a nuclear reactor in order to determine the amount of manganese present. The upstream samples did not indicate backflow. That is, the manganese concentration upstream did not increase over the threshold value.

No correlation was made between manganese tracer and other hazardous substances. Further work is needed to validate and develop the practical application of this promising test method.

### 4.2.3 Repeatability and Accuracy

With the exception of ASSE 1001 and ANSI A112.1.1.1971 (pipe Applied Atmospheric Type Vacuum Breakers), no other standards require data repeatability (the average of three test runs are required) or measure accuracy. However, an acceptable value of data repeatability is not mentioned (departure from the average).

### 4.2.4 Limit Testing, Failure Modes, Maintainability and Field Testing

The standards do not require that devices be cycled to failure over operating conditions of temperature, pressure, and flow in order to detect failure modes. The standards do not require that devices fail safe or that devices indicate when they have failed (except for RPBD). RPBD discharges water from its ports on failure of check valves or relief valve but this does not necessarily mean such failure would be observed or detected. As noted earlier, no test methods determine whether a device can prevent backflow of a pollutant when subjected to conditions of backflow under operating conditions of temperature, pressure, and flow. Guidelines and tests for mean time between failure, mean time to maintain, mean time to repair, level of spare parts required, availability of repair parts are not considered.

FCCCHR and IAPMO Standards require a twelve-month field test of RPBD and DCVA. Although the standards do not go into detail concerning the tests, the following is the general procedure as given in an unpublished FCCCHR paper [32]: See Section 3.4.1.

(a) One or more units of each size and model are submitted from the manufacturer's stock. These devices shall pass the laboratory test prior to the field evaluation.

(b) The manufacturer arranges for the placement of at least three devices, of each size and model tested in the laboratory in the field installation. FCCCHR approves of the selected field location. The location must not be on a fire service where normally a no-flow condition exists almost continuously. The devices must not be placed where the flow is maximum all of the time. Also, an RPBD under test must not be placed in a pipeline where there is potential for hazardous backflow if the RPBD should fail during the field test. The devices must be located in pipelines where the water supply can be turned off for short periods of time as required by test procedures.

(c) The field evaluation consists of a monthly test of all of the devices on the field test program.

The field test purpose is to assure that a device will function under actual operating conditions. ASSE Standards do not require a field test and as a result their standards do not give assurance of satisfactory performance under operation conditions. Field testing is presently performed only for RPBD, DCVA and PVB. AVB is not field tested. It appears that this aspect of testing requires additional study. Certainly, assurance should be given that all devices will perform in the field.

## 5. SUMMARY OF FINDINGS

The following is a summary of findings concerning backflow protection devices, test methods, and laboratories.

### 5.1 Air Gap (AG)

An air gap provides positive protection against backflow of liquid and solid contaminants. However, authorities recognize that an air gap may be defeated through attachment of by-passes[1]. This attribute of AG is no different than that of other devices such as the electric fuse which can be defeated in households by use of coins or other means that result in burned wiring and houses.

### 5.2 The Reduced Pressure Backflow Device (RPBD)

The RPBD provides good protection against backflow in high risk situations. This device is in its weakest mode of operation when subjected to both back pressure and back-siphonage conditions simultaneously. NBS tests have demonstrated that one RPBD would backflow when the check valves leaked under such conditions. The standards for RPBD do not have requirements or test methods for back-siphonage. However, one manufacturer's literature states that the RPBD is absolute protection against back-siphonage conditions. Administrative authorities use RPBD for protection against both back-siphonage and back pressure within the water service lines to hazardous locations such as sewage treatment plants. The probability of simultaneous back pressure and back-siphonage conditions is unknown but is presumed to be much smaller than the likelihood of either event singly. Thus, RPBD's clearly do provide protection. The RPBD's only means of protection under simultaneous conditions of both back-siphonage and back pressure is the tightness of the check valve on the upstream side of the zone. For this reason, a periodic test and maintenance program is essential for RPBD (some authorities test RPBD at least annually) [1]. The use of strainers is considered helpful by some, but others feel that strainers can cause excessive pressure drop (ASSE's standards require strainers ahead of both RPBD and DCVA but FCCCHR does not).

### 5.3 Fail Safe Devices

No device currently used to prevent backflow provides a positive indication of the device function or malfunction in the way that a fuse or circuit-breaker protects an electrical circuit. An RPBD can be observed to discharge fluid as an indicator only if an informed person happens to be near the device at the time the backflow condition exists.

The ASSE standard 1001 does not consider means to test AVB for malfunction in the field [20].

Although Barometric Loops are used in large laboratory complexes to protect against backflow of potentially hazardous substances, there are questions concerning its adequacy to protect against transfer of contaminants by air bubbles if an air water separator is not used. Additional studies concerning transfer of pollutants by diffusion and by air have been recommended by the National Institutes of Health [27].

HCVB with a check valve is in its weakest mode of operation when subjected to back pressure which occurs when the terminal end of the garden hose is elevated above the HCVB. In this situation the device does give protection as long as the check valve does not leak. More protection could occur if the devices were located above the terminal end of the hose, though such an arrangement may not be practical in many cases. The HCVB without the check valve should not be used on garden hoses because this type of HCVB does not prevent backflow caused by back pressure. This type HCVB (without a check valve) is merely a special AVB and should be tested under ASSE type 1001 methods.

## 5.4 Realistic and Usable Test Methods

The AWWA standard for RPBD and DCVA does not contain test methods or implied tests. FCCCHR and IAPMO indicate the type of tests that are to be performed but do not give details of the test methods or test setups for hydraulic laboratory tests. ASSE standards specify test methods and test setups.

In the case of RPBD, the current standards do not consider back-siphonage conditions and yet the device is used for this condition in actual practice. Similarly RPBD tests do not involve actual demonstration of functional performance i.e., prevent backflow of actual contaminants under simulated use conditions.

The RPBD standards are not consistent concerning the necessity for field test. ASSE does not require a field test and FCCCHR and IAPMO require a twelve month field test. Further, FCCCHR and IAPMO standards do not provide definitive detail concerning how to perform the tests. Although PVB is field tested, AVB is not field tested.

The standard for HCVB (check valve type) tests the device with water discharging from its air inlet ports. This is reasonable in light of the fact that the device is designed to relieve back pressure through its ports. However, some authorities, Dawson and Kalinske, [3] have said that one of the main requirements to good vacuum breaker design and installation is to prevent the discharge of water from the air inlet ports. Such discharge is alleged to cause blockage of the ports by a build up of lime deposits. Further study is required to determine if this condition will occur with HCVB. Port pollution possibilities should also be studied.

No standard requires the use of actual or simulated contaminants or an appropriate tracer to demonstrate quantitatively or qualitatively the ability of the devices to prevent backflow. All present tests are indirect in that they show that valves do not leak or that relief valves function. The water-rise test for AVB is the most realistic test, but it is not concerned with upstream measurements to determine if a contaminant (air, aerosol, etc.) has passed into the inlet of the device.

With the exception of the ASSE/ANSI Standard for AVB, no other standard specifies data repeatability or measurement accuracy.

Limit testing to determine failure modes or other tests to determine mean-time-to-maintain or to-repair, and level of spares required or availability of spares are not considered by standards. Many of these devices are very expensive, costing thousands of dollars.

The standards do not explicitly require periodic review of test methods/equipment.

## 6, CONCLUSIONS AND RECOMMENDATIONS

### 6.1 Conclusions

1. Existing backflow prevention devices do provide protection against backflow. However, insufficient data appears to exist to evaluate quantitatively the effectiveness of these devices, the risks associated with various types of system designs, or the relative advantages of various devices in particular installations.

2. None of the existing devices is fool proof. Most do not provide positive indication of failure, when it occurs, or device usage when backflow conditions arise; nor are any of the devices used fail-safe. There is some apparent misconception of the test methods regarding the capabilities of the RPBD and HCVB (with check valves) in particualr concerning functional performance under all normal service conditions (i.e., combined back pressure and back-siphonage conditions and possible lime deposits blocking HCVB air ports). HCVB (without a check) should not be used with garden hoses.

3. A.S.S.E. Standards are the only standards that have detailed test methods, i.e., definitive test procedures and test setups. However, the standards are inconsistent concerning the application of realistic tests. For instance (other examples are in section 4.2), if a device is designed to operate in water that is 32°F, the device should be tested to demonstrate the ability to prevent backflow at that temperature. AVB's are tested at their operating temperatures for leaks and distortion of parts but not back-siphonage. RPBD's do not have test methods that show the device will operate at design temperatures. Although both AVB's and RPBD's are used to protect against back-siphonage, AVB's are tested with vacuum and RPBD's are not. In fact no standard of FCCCHR, IAPMO, or AWWA specifies performance for RPBD under vacuum conditions simulating back-siphonage. FCCCHR and IAPMO require a twelve month field test, but ASSE does not. Some standards do not explicity spell out test methods or equipment. Others are prescriptive and provide no means for testing of innovative devices. No existing standards test devices for functional performance under full actual or simulated service life conditions. The test methods, however, do show that devices provide protection. These test methods could be much improved by the use of realistic service condition simulation.

4. In fairness to the backflow prevention device industry and the standards to which they adhere it is appropriate to note:

(a) The backflow prevention device industry provides an extremely valuable National service in the manufacture and sales of devices which adhere to recognized standards. The purpose of this work was not to discredit any party concerned, but to present constructive criticism when required.

(b) Although the devices of a particular manufacturer may be recognized in this report, tests presented and discussed here do not in any way discredit specific products.

## 6.2 Recommendations

### 6.2.1 First Order Priority

(a) It is recommended that a study be carried out concerning the reliability of devices that have been field tested versus the reliability of devices that have not been field tested in order to resolve the apparent controversy concerning whether to require field test or not.

(b) It is recommended that a functional performance test and performance standard based on using a quantitative tracer (pollutant) be developed that would be applicable for testing all classes of devices including innovative devices under simulated life cycle conditions. During the test, the devices would be subjected to a program of various water supply operating conditions including back-siphonage to determine the ability of the device to prevent the backflow of the tracer or simulated contaminant. See Section 4.2.2.7.

(c) It is recommended that a program be undertaken to develop a positive fail-safe means of indicating or calling operator attention to any backflow condition particularly in high-hazard locations. Ideally a device corresponding to an electrical fuse or circuit breaker would be desirable.

### 6.2.2 Second Order Priority

(a) It is recommended that means be developed that would allow the homeowner or plumbing inspectors a ready means to determine whether or not an AVB or HCVB or similar device is functioning properly and has not failed.

(b) It is recommended that manufacturers provide definitive data concerning reliability, maintainability, mean-time-to-maintain, and mean-time-to-failure on their devices for various locations and water type, etc.

(c) It is recommended that a study be conducted to determine the level of barometric loop usage and whether or not the barometric loops in use are using air-water separators [19].

(d) It is recommended that a study be carried out concerning the use of strainers ahead of RPBD, DCVA, PVB, and AVB. Such strainers would tend to prevent the passage of particles that could foul the checks of devices.

(e) It is recommended that a back-siphonage detection monitoring system be developed. This should include sampling at statistically selected high-hazard locations such as sewage treatment plants, hospitals, and hazardous industrial and commercial locations. Such information would define the magnitude of the problem and pinpoint recurring low pressure conditions in the water supply system that must be corrected. Better data on backflow incidents is needed to provide a basis for developing and evaluating alternative program options in this field.

(f) It is recommended that a rational approach be developed to determine the order of magnitude of the risk presented by any particular type of hazard on a premise as related to other premises and the water utility itself. For instance, hazardous condition on a premise of a given type located in the middle of a highly populated metropolitan area would present a greater risk in terms of population density alone than the same condition on a premise located outside the metropolitan area where the population density is very much lower. This method would provide a means of establishing priorities for the installation of devices of various types. This approach would be based on information on adverse water pressure fluctuations and backflow incidents reported in paragraph (e) above.

(g) It is recommended that the HCVB's be studied to obtain answers to the following questions:

(i) Will the air ports become blocked with lime deposits to make them ineffective.

(ii) Is there a high risk of contamination at the air ports?

(iii) Would the device give greater protection installed at the nozzle end of the hose instead of the sillcock end?

## 7. ABBREVIATIONS AND DEFINITIONS

The following Abbreviations have been used in this report. The source of definitions are identified at the end of the section.

| | |
|---|---|
| Air Gap | AG |
| American National Standards Institute | ANSI |
| American Society of Mechanical Engineers | ASME |
| American Society of Plumbing Engineers | ASPE |
| American Society of Sanitary Engineering | A.S.S.E.<br>or ASSE |
| American Standards Association | A.S.A.<br>or ASA |
| American Water Works Association | A.W.W.A<br>or AWWA |
| Antisiphon flush valve ball cock | AFVBC |
| Atmospheric Type Vacuum Breaker | AVB |
| Backflow Preventer with Intermediate Atmospheric Vent | BPIA |
| Ball Cock | BC |
| Barometric Loop | BL |
| Building Officials and Code Administrators International, Inc. | B.O.C.A.<br>or BOCA |
| Critical Installation Level | C-I-L |
| Double Check Valve Assembly | DCVA |
| Environmental Protection Agency | EPA |
| Feet or foot | ft |
| Foundation for Cross-Connection Control and Hydraulic Research | FCCCHR |
| Foundation for Cross-Connection Control Research | FCCCR |
| Gallons per minute | g.p.m.<br>or gpm |
| Hose Connection Vacuum Breaker | HCVB |
| Inch or inches | in |
| International Association of Plumbing and Mechanical Officials | I.A.P.M.O.<br>or IAPMO |
| Iron pipe size | i.p.s.<br>or ips |
| Library of Congress "Science Policy, a working Glossary" | LCSPWG |
| Los Angeles Department of Water and Power | DWP |
| Milliliters | ml |
| Minute | min |
| National Association of Plumbing-Heating-Cooling Contractors | NAPHCC |
| National Bureau of Standards | NBS |
| National Sanitation Foundation | NSF |
| National Standard Plumbing Code | NSPC |
| Oak Ridge National Laboratory | ONRL |
| Pounds per square inch | p.s.i.<br>or psi |
| Pounds per square inch, gage | psig |
| Pressure type vacuum breaker | PVB |
| Product Standard | PS |
| Reduced Pressure Principle Backflow Prevention Device | RPBD or<br>or RP |

## 7.2 Definitions

Administrative Authority: The individual official, board, department, or agency established and authorized by a state, county, city or other political subdivision created by law to administer and enforce the provisions of the plumbing code or of a cross-connection control program. (NSPC & NBS)

Air Gap: An air gap in a potable water distribution system is the unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or faucet supplying water to a tank, plumbing fixture or other device and the flood level rim of the receptacle. (NSPC)

Air Gap Separation: The physical separation between the free-flowing discharge end of a potable water supply pipeline and an open or non-pressure receiving vessel. The width of separation shall be at least that specified in ANSI A112.1.2 - 1973 (FCCCHR & NBS)

Air Inlet: The opening or series of openings through the body of a vacuum breaker connecting the free atmosphere with the liquid passageway of the device (ASSE 1001)

Ambience (noun): The surroundings or environment of a place or thing used in experimental research to indicate, e.g. the temperature, humidity pressure, gases, and radiation in the space surrounding the object of an experiment. (LCSPWG)

Analysis: The action of taking something apart and examining its components. (The very extent of the use of the term may seem to deprive the word of much of its meaning. It is employed in a great many different senses, and in many combinations. The meaning seems to depend somewhat on the discipline connected with its use.)
The notion that analysis is an identifiable and describable process independent of the discipline involved or the item being analyzed is suggested by the large number of compound words hyphenated with it, for example: value-, failure-, cost-effectiveness-, operations-, systems-, stress-, reliability-, maintainability-, etc. (LCSPWG & NBS)

Atmospheric Air: Air of the surrounding atmosphere and at its existing pressure. (ASSE 1013)

Backflow: The unintentional reversal of flow in a potable water distribution system which may result in the transport of harmful materials or substances into the other branches of the distribution system. (NBS)

Backflow Connection: The point of joining of potable water piping with equipment, fixtures, or other piping that may be contaminated. (NBS).

Backflow Preventer: Any mechanical device, whether used singly or in combination with other controls, that may automatically forestall the possibility of an unintentional reverse flow in a potable water distribution system. (ASSE 1001)

Backflow Preventers with Intermediate Atmospheric Vent: These devices have two independently operating check valves separated by an intermediate chamber with a means for automatically venting the chamber to the atmosphere. The check valves are force loaded to a normally closed position and the venting means is force loaded to a normally open position. These devices can operate under continuous or intermittent pressure conditions. (ASSE 1012)

Backflow Preventers, Reduced Pressure Principle, Back Pressure: These devices consist of two independently acting check valves, internally force loaded to a normally closed position, and separated by an intermediate chamber (or zone) in which there is an automatic relief means for venting to atmosphere, internally force loaded to a normally open position. These devices are designed to operate under continuous pressure conditions. (ASSE 1013)

Backflow Preventers, Double Check Valve Type, Back Pressure: These devices consist of two independently acting check valves internally force loaded to a normally closed position and designed and constructed to operate under intermittent or continuous pressure conditions. (ASSE 1015)

Back Pressure: Pressure created by any means in the water distribution system on the premises, which by being in excess of the pressure in the water supply main could cause backflow. (NBS)

Back-Siphonage: The backflow of possibly contaminated water into the potable water supply system as a result of the pressure in the potable water system becoming unintentionally less than the atmospheric pressure in the plumbing fixtures, pools, tanks or vats that may be connected to the potable water distribution piping. (NBS)

Ball Cock: A water supply valve opened or closed by means of a float or a similar device and used to supply water to a tank. (ASSE 1001)

Ball Cock, Antisiphon: A ball cock that contains an antisiphon device in the form of an approved air gap or a vacuum breaker which is an integral part of the ball cock unit and which is positioned on the discharge side of the water supply control valve. (ASSE 1001)

Check Valve Assembly: A combination of spring and weight loaded check valves with resilient discs for the intended purpose of preventing back pressure backflow in a water supply line. Assembly is usually furnished with test cocks for field testing the tightness of the check valves. Some assemblies include a vacuum breaker to admit atmospheric air downstream of the assembly. (ASSE 1013)

Community Water System: A public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents. "Non-community water system" means a public water system that is not a community water system (EPA 141.2.(e)) (see public water system).

The purpose of defining "Community water system" is to allow appropriate regulatory distinction between public water systems which serve residents on a year-round basis and public water systems which principally serve transients or intermittent users. The possible health effects of a contaminant in drinking water in many cases are quite different for a person drinking the water for a long period of time than for a person drinking the water only briefly or intermittently. Different monitoring requirements are appropriate for the two types of systems. (EPA 141.2(e))

Constraint: A limiting condition to be satisfied in the design or operation of a system. For example: the total cost may be a constraint, or the percentage of system life consumed in downtime, or the compatability of a system with other systems. (LCSPWG)

Contamination: The admission of contaminants into a potable water supply (ASSE 1013)

Contaminants (as applicable to standards for backflow prevention devices): Materials (solids or liquids or gases) which may be added unintentionally (or intentionally) to the potable water supply and cause it to be unfit for human or animal consumption. (ASSE 1013)

Contaminants (as applicable to the Safe Drinking Water Act): Any physical, chemical, biological, or radiological substance or matter in water. (EPA 141.1(6))

This definition, in the review of Section 141.2 of the National Interim Primary Drinking Water Regulations of December 24, 1975, was critized for its breadth. The term as defined includes virtually any constituent in water, including constituents considered to be harmless or even beneficial. The definition was taken directly from Section 1401(6) of the Safe Drinking Water Act. It is not intended to suggest that all constituents of water are undesirable, but rather is intended to permit the regulation of any constituent which may be harmful. (see definition of maximum contaminant level)

Control Valve: A valve that is operated each time water is supplied to or shut off from a receptacle or plumbing fixture. Familiar examples are faucets and sill cocks. (ASSE 1001)

Cost/Benefit Analysis: The relation between social benefits and social costs associated with the operations of a technical system under study. The benefits and the costs include direct and indirect effects. Monetary equivalents are sometimes assigned to the non-materialistic values for the purpose of comparison and to clarify the relationships between benefits and costs. (LCSPWG)

Cost/Effectiveness: This is a term widely used in systems analysis, and has been carried over into budgeting analysis. It signifies the ratio, over an explicit and finite time-span, of cost in dollars and other tangible values to effectiveness. In the military area, in which cost/effectiveness analysis originated, the payoff was defined in terms of the effectiveness of the military system. In the civilian area, "effectiveness" is replaced by "benefit." Admittedly, benefits in social systems are even more difficult to define than effectiveness in military systems. (LCSPWG)

Criterion (plural Criteria): A standard or an explicit measure by which to evaluate any activity or thing. Criteria may be quantitative or qualitative and objective or subjective. In effectiveness analysis, criteria are the elements to be measured to determine costs and benefits. (LCSPWG)

Critical Installation Level: A designated operational limitation prescribing a safe height on installed vacuum breaker above the flood-level rim of the fixture or receptacle served. In the absence of a physical mark on the device, indicating a height measurement reference point, the extreme bottom of the device shall be considered the height reference point. (ASSE 1001)

Cross Connection: Any physical connection or arrangement between two otherwise separate piping systems, one of which contains potable water and the other either water of unknown or questionable safety or steam, gas, chemicals or other substances whereby there may be a flow from one system to the other, the direction of flow depending on the pressure differential between the two systems. By-pass arrangements, jumper connections, removable sections, swivel or change-over devices and other temporary or permanent devices through which or because of which backflow can or may occur are considered to be cross-connections. (FCCCHR)

Cross Connection, Point of: The specific point or location in a potable water distribution where a cross connection exists. (FCCCHR)

**Effectiveness**: In system analysis, the term effectiveness is an aggregative expression intended to encompass all performance qualities of a system that is likely to be judged as relevant. The term describes a condition in which a system or program possessing it has been designed to satisfy at some pre-determined level all criteria selected as relevant. The term does not imply perfection but essential adequacy in all significant categories of performance. An effective design will result from the total of design decisions among options, selecting the optimal trade-off at each decision point, to satisfy all conceivably relevant internal and external criteria, quantitative and qualitative, tangible and intangible of performance and environmental compatibility. The concept includes such obvious criteria as cost, efficiency, and reliability. It also involves total life cost, maintainability, maintenance of the state-of-the-art modernity, compatibility with expected operating environment, recycle or scrap value, and such other criteria as the design engineer and the customer (or sponsor) consider relevant. (LCSPWG)

**Flood Level Rim**: That level from which liquid in plumbing fixtures, appliances or vats could overflow to the floor when all drain and overflow openings built into the equipment are obstructed. (NBS)

**Hazard**: A possible source of danger or peril; also a condition that tends to create or increase the possibility of loss or harm. (NBS)

**Hazard, Health**: An actual or potential threat, of contamination or pollution of a physical or toxic nature to the potable water system to such a degree that there would be a danger to health. (FCCCHR)

**Hazard, Minimal**: A connection made to the potable water system whereby the risk from backflow occurring would entail the contamination of the potable water with objectionable but non-toxic substances such as steam, air,food, beverage etc. (NBS)

**Hazard, Plumbing**: A plumbing type cross-connection in a consumer's potable water system that has not been properly protected by a vacuum breaker, air gap separation, or other suitable device. (FCCCHR)

**Health Agency**: The organization established by law to have jurisdiction over the water supply quality. (FCCCHR)

In the National Interim Primary Drinking Water Regulations, "State" means the agency of the State government which has jurisdiction over public water systems. During any period when a State does not have primary enforcement responsibility pursuant to Section 1413 of the Safe Drinking Water Act, the term "State" means the Regional Administrator, U. S. Environmental Protection Agency. (EPA 141.2(h))

Maximum Contaminant Level: The maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under circumstance controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition. (EPA 141.2(c))

Model: A simplified description of a process or system, or the interaction of either with its environment. (LCSPWG)

Potable Water: Water from any source which has been approved for human consumption by the health agency having jurisdiction. (FCCCHR)

Potable Water: Water that meets the maximum contaminant level requirements of the National Interim Primary Drinking Water Regulations and which has been approved for human consumption by the health agency having jurisdiction. (EPA)

Pollution: As used in this report the word is equivalent to contamination in the sense that substances in the water are either undesirable or harmful. FCCCHR credits the California State Health and Safety Code with differentiating the two words: contamination of water creates health hazards (q.v.) and pollution of water creates minimal hazards (q.v.). (NBS)

In view of the EPA definition of a contaminant, the word "pollutant" may provide the means of defining or designating the "contaminants" that are undesirable or harmful.

Pressure, Absolute: Pressure measured on a scale having a zero value approximately 14.7 $lb/in^2$ below normal atmospheric pressure.

Pressure, Atmospheric: The pressure exerted in every direction at any given point by the weight of the atmosphere.

Pressure, Hydrostatic: Pressure exerted by or existing within a liquid at rest with respect to adjacent bodies.

Public Water System: A system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year. Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system and (2) any collection or pre-treatment storage facilities not under such control which are used primarily in connection with such system. A public water system is either a "Community Water System" or a "Non-Community Water System". (EPA 141.2(e))

Service Connection: The point at or near the water main where the water purveyor delivers potable water to the consumer's water system. Usually the water purveyor loses jurisdiction and sanitary control over the water at the service connection.

Trade-off: The foregoing of some portion of one benefit in order to achieve some unused portion of another benefit: (or) foregoing some portion of a benefit in order to achieve a reduction in some portion of a cost: (or) accepting an increased portion of one cost in order to receive a decrease in the portion of another cost. Other more complicated permutations of this concept can be suggested. The term is in wide usage. (LCSPWG)

Toxic: Poisonous [see Code of Federal Regulations, Title 21, Food and Drugs Parts 170 to 299, 21 CFR 170.1, Section 191.1, Hazardous Substances. Definitions.] (ASSE 1011)

Vacuum: Any space in a water-supply system from which water has been displaced by water vapor, air, or other gases, and in which the pressure is less than the prevailing atmospheric pressure. (RP 1086)

Vacuum Breaker, Atmospheric Type: A back-siphonage prevention device which is designed to operate under pressure only when water is flowing through the system and not under static, standing conditions. Must be installed upstream of any shut-off or control valve or means. (ASSE 1011)

Vacuum Breaker, Pressure Type: A back-siphonage prevention device which can be subjected to continuous pressure, flowing, static, or both. (ASSE 1011)

Vacuum Breaker, Hose Connection Type: A backflow prevention device designed to be attached to an outlet having a hose connection thread. It may be either atmospheric or pressure type. (ASSE 1011)

Water Hammer: The term used to identify the hammering noises and severe shocks that may occur in a pressurized water system when flow is halted abruptly by the rapid closure of a valve or faucet. (NBS)

Water Purveyor: The owner or operator of the public potable water system supplying an approved water supply to the public. The purveyor operates under a valid permit from the State Department of Public Health or the local health agency having jurisdiction. (FCCCHR)

Water Supply Approved: Any public potable water supply which has been investigated and approved by the State Department of Public Health or the local health agency having jurisdiction. The system must be operating under a valid health permit. (FCCCHR)

Sources of definitions are identified by code as follows:

ASSE 1001 --------------Standards of the American Society
ASSE 1011 of Sanitary Engineering
ASSE 1012 see reference in Section
ASSE 1013 and 1015 [20] [21] [22] [23] [24]

EPA----------------------------EPA, Water Programs, Part 141,
National Interim Primary Drinking
Water Regulations, dated Dec. 24, 1975

FCCCHR-------------------------Foundation for Cross Connection Control
and Hydraulic Research, see Reference [29]

LCSPWG-------------------------Library of Congress "Science Policy-
a Working Glossary" see Reference [37]

NBS----------------------------When used alone, the definition was
generated by the authors, when used jointly,
the definition was modified from one
published by the other source.

NSPC---------------------------National Standard Plumbing
Code Reference [38]

RPI086-------------------------Hunter, Golden, and Eaton
Reference [2]

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# 9.0 ACKNOWLEDGMENT

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# 10. APPENDIX

## 10.1 Vacuum Dissipation Calculations

Dawson and Kalinske present the following useful equations in their report on "Plumbing Cross-Connections and Back-Siphonage Research," pages 28 and 29 [3]. The introductory paragraph concerning these equations is as follows:

> "In order that some idea may be had of the time required to dissipate vacuums in different-size volumes, an analysis will be made of this particular problem. It is to be remembered that the rate of air flow in pounds per second through any given opening remains constant for any vacuum greater than 14 inches of mercury. Therefore, the time required for a vacuum in a volume V to be reduced to the critical pressure of 14 inches of mercury vacuum, can be obtained from the following expression :

$$t_1 = \frac{V(W_c - W_i)}{Q_a} \qquad \text{Equation (11)}$$

Where: $t_1$ = seconds of time required.

$W_c$ = weight of air per cubic foot at critical pressure $P_c$. (lbs/ft$^3$)

$P_c$ = $0.53P_a$ = 14 inches of mercury vacuum. $W_c$ is to be determined by considering adiabatic expansion from $P_a$ to $P_c$. $P_a$ = atmospheric pressure (lbs/ft$^2$)

$W_i$ = Unit weight of air at initial pressure and temperature in the volume into which air is flowing. (lbs/ft$^3$)"

$Q_a$ = pounds per second of air flow into the vacuum for vacuums exceeding 14 inches of mercury. $Q_a$ = 50CA, where C = the discharge coefficient of the opening through which air enters the vacuum. A = the area of the opening in square feet.

The unit weight of air after adiabatic expansion from atmospheric pressure to any pressure, P, can be determined from the following formula:

$$W = W_a \left(\frac{P}{P_a}\right)^{1/k}$$

Where: $W_a$ = unit weight of atmospheric air (lbs/ft$^3$)

$k = 1.4$ for air

The time to dissipate vacuums less than 14 inches mercury is given by Dawson and Kalinske as follows:

$$t_1 = \frac{0.00086\ V}{CA} \qquad \text{Equation (15)}$$

They give the following example:

> "Taking an example where V is 10 gallons or 1 and 1/3 cubic feet, find the time required to dissipate the vacuum from 29 inches of mercury to atmospheric pressure if air flows in through a 3/4-inch circular opening having a flow coefficient of 1/2. From equation (11), the time required to reduce the vacuum from 29 inches to 14 inches is 0.8 seconds. To reduce the vacuum from 14 inches of mercury to atmospheric pressure required about another 0.8 seconds. Therefore, the total time for dissipation of the vacuum is 1.6 seconds. The persistence of a vacuum for such a short time would obviously prevent the maximum back-siphonage effect. A 10 gallon volume is equivalent to about 100 feet of 1 1/2-inch pipe. The time required for vacuum dissipation in other volumes would be in proportion."

From Dawson and Kalinske's equation above, (11) and (15), a simplified equation for the dissipation of vacuum to atmospheric pressure can be developed as follows for the total time $t_t$.

$$t_t = t_1 + t_2$$

$$t_t = \frac{W_c - W_i)V}{Q_a} + \frac{0.00086\ V}{CA}$$

By substitution of the parameters of the above example into equation 11, it can be shown that $(W_c - W_i) = 0.0460$ for Dawson and Kalinske assumed conditions. Substituting this value into the above equation gives:

$$t_t = \frac{0.0460\ V}{50x1/2x0.785\ D^2} + \frac{0.00086\ V}{1/2x0.785\ D^2}$$

$$t_t = \frac{0.00234\ V}{D^2} + \frac{0.00219\ V}{D^2} = \frac{0.00453\ V}{D^2}$$

Where D = diameter in feet.

For a diameter d in inches

$$t_t = \frac{0.00453\ V}{d^2} \times 144 = \frac{0.65232\ V}{d^2}$$

For example in section 2.1 of this report, where V = seven and one third gallons = 0.98 $ft^3$ and d = 0.375 inches, the total time is as follows:

$$t_t = \frac{0.65232 \times 0.98}{0.1406} = 4.547 \text{ seconds}$$

## 10.2 The Navy Survey Form

The Navy survey form is reproduced here to aid in the interpretation of the data gathered for table 2 on page 11.

BACKFLOW PREVENTION POLICY
SURVEY FORM

NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California 93043

Mechanical and Electrical Engineering Department
Work Unit: YF38.534.006.01.007, Backflow Prevention Devices

BACKFLOW PREVENTION SURVEY

The following questions concern policies and regulations governing the protection of a potable water source which supplies a customer having a known or potential cross-connection to a health hazard. Of specific interest are the requirements for backflow preventers at vessel watering points at piers and wharves.

Responding Agency

Name:________________________________________

Address:______________________________________

Phone:_______________________________________

Respondent: Name/Title_________________________

Please complete this questionnaire by checking (✓) the appropriate answer to each question that applies to your backflow prevention policies.

1.a. What is the minimum backflow prevention you require where a health hazard exists?

( ) Air gap separation required (reduced pressure devices and double check valve devices not allowed).
( ) Reduced pressure principal backflow preventer required.
( ) Double check valve assembly required.
( ) Other protection.________________________________________
( ) No protection specified.

1.b. What minimum protection do you require at vessel watering points at piers and wharves?______________________________

______________________________________________________________

______________________________________________________________

2. If reduced pressure principal devices are used, what certification or approval of the device do you require prior to its installation?

( ) Full approval by the Foundation for Cross-Connection Control Research at the University of Southern California.
( ) Provisional approval by the above Foundation.
( ) Laboratory test only by the above Foundation.
( ) Other certification or approval. (Please specify and list devices approved.)______________________________
( ) No certification or approval required.

3. The Foundation for Cross-Connection Control Research has recently changed the field test requirement, before granting full approval, from a three-year test to a one-year test with more frequent inspection. If you currently require full or provisional approval will you:

( ) accept all devices approved under the new one year test program.
( ) accept only those devices previously approved under the three-year test program.
( ) provide an alternate policy. (Please specify)______________

______________________________________________________

4. If devices now in service were previously approved by a certifying authority, and if they do not have their certification renewed, or if it is rescinded by that authority, what will your policy be?

( ) Replace these devices at the earliest possibility with an approved device.
( ) Replace these devices at the first sign of malfunction with an approved device.
( ) Accept the device as originally approved.
( ) Other policy. (Please specify)______________________________

______________________________________________________

5. The cost of purchasing and installing a backflow prevention device is borne by the:

( ) water utility.
( ) customer.

6. Please list the manufacturer, model, and size of reduced pressure principal backflow preventers which have been installed in your water system. Reduced pressure devices have been used for how many years?____

| Manufacturer | Model | Size | No. Installed |
|---|---|---|---|

7. Please indicate your maintenance and inspection policy regarding reduced pressure principal devices.

a. Frequency of inspection____________________

b. Frequency of scheduled testing____________________

c. Frequency of scheduled maintenance____________________

d. Work required during scheduled maintenance____________________

____________________

e. Who performs inspection____________________

testing____________________

maintenance____________________

f. Who pays for inspection____________________

testing____________________

maintenance____________________

8. Please describe any malfunctions, failures, or problems encountered with reduced pressure preventers, including the make, model, and size of unsatisfactory units, the date of installation, and length of operation before malfunction.

____________________

____________________

____________________

9. Repeat question 8 for double-check valve assemblies.

10. Is freezing a problem in your area?

How are these units protected from freezing?

What are the effects from freezing on reduced-pressure devices and double-check valve assemblies?

11. Do you foresee any changes in your existing backflow prevention policy in the near future?

12. Other comments. (Please attach a copy of any regulations applicable to this survey.)

## 10.3 Procedures for a National Voluntary Laboratory Accreditation Program.

The National Voluntary Laboratory Accreditation Program was promulgated by the publication of procedures in the Federal Register on February 25, 1976. It was stated that the goal of this program is to provide in cooperation with the private sector a national voluntary system to examine upon request the professional and technical competence of private and public testing laboratories that serve regulatory and nonregulatory product and certification needs. The program is also intended to accredit those laboratories that meet the qualifications which will be established under these procedures.

The program has been set up as Part 7 of Title 15 in Commerce and Foreign Trade. For this reason the document is divided into eighteen sections numbered from 7.1 through 7.18. Because some of the sections are quite lengthly and tedious to read, a format with sidenotes has been chosen for the presentation of Part 7 in this paper. Also the format incorporated the following arrangements:

1. The first line of the first sentence in a paragraph is indented.

2. Subsequent sentences in the same paragraph are not indented but, after a line space, begin at the margin.

3. A small circle marks the location of each sentence and a dash through a circle represents supporting statements or phrases for a previous sentence.

4. Where sentences are long, the ideas are separated by breaking the line and continuing after a single line space.

## 7.1 Purpose

- The purpose of this part is to establish procedures under which a National Voluntary Laboratory Accreditation Program will function.

## 7.2 Description and goal of program

7.2(a)
This system would examine competence of testing laboratories

- This program establishes a national voluntary system that would examine the professional and technical competence of testing laboratories that serve regulatory and non-regulatory product evaluation and certification needs.

Laboratories that meet qualifications would be accredited

- Laboratories that meet the qualifications established pursuant to the procedures set out below would be accredited.

Periodic checks and examinations will be required

- This program will also require those laboratories that are accredited to maintain their qualification status through periodic checks and examinations.

7.2(b)
Program will make maximum use of all existing activities

- The program will seek through coordination and consultation, to maximize benefits derived from other laboratory examination and accreditation activities.

Would avoid duplication of other programs

  - In this way, it is intended that the program will avoid duplication of other laboratory examination or accreditation programs conducted by the public and private sectors.

Secretary will insure close coordination and consultation

  - To this end, the Secretary will insure that close and continuing coordination and consultation is undertaken and maintained with interested representatives of Federal, State and local governments and of the private sector, including those from professional and trade associations and societies.

7.2(c)
To serve needs of industry, consumers and the Government

- The intended goal of this program is to serve, on a timely basis, the needs of industry, consumers, the Government, and others by accrediting this nation's testing laboratories.

To promote technical competence

  - The achievement of this goal would be sought by fostering and promoting a uniformly acceptable base of professional and technical competence in testing laboratories

To establish a background of experience

  - and by establishing a background of experience necessary to the orderly evolution of a laboratory accreditation system designed to serve national needs as they develop.

## 7.3 Definitions

7.3(a)
Secretary

- The term "Secretary" means the Secretary of Commerce or his designee.

7.3(b)
Product

- The term "Product" includes the plural thereof and means a type or a category of manufactured goods, constructions, installations and natural and processed materials or those associated services whose characterization, classification or functional performance determination is specified by standards.

7.3(c)
Criteria
Committee

- The term "Criteria Committee" means a National Laboratory Accreditation Criteria Committee appointed by the Secretary under these procedures.

7.3(d)
Person

- The term "person" means associations, companies, corporations, educational institutions, firms, government agencies at the Federal, State and local level, partnerships and societies, as well as divisions thereof, and individuals.

7.3(e)
Testing
Laboratory

- The term "testing laboratory" means any "person," as defined above, whose functions include testing, analyzing or inspecting "products," as defined above, and/or evaluating the designs or specifications of such "products" according to the requirements of applicable standards.

7.3(f)
General
Criteria

- The term "general criteria" means those characteristics of a testing laboratory commonly found in, and generally expected of, such a laboratory serving the product under consideration. See in this connection Sec. 7.7(a).

7.3(g)
Specific
Criteria

- The term "specific criteria" means those detailed requirements deemed essential to assuring an acceptable examination and evaluation of the testing function performed by a testing laboratory in performing specific tests related to identified standards for the product under consideration. See in this connection Sec. 7.7(a).

### 7.4 Finding of need to accredit testing laboratories.

7.4(a)
Any person may
initiate request
for finding of
need.

- Any person may request the Secretary to find that there is a need to accredit testing laboratories which render services regarding a specific product so that it may be ascertained whether such product meets the requirements of applicable standards.

7.4(b)
Request must
include specific
information on
product standards,
test methods.

- Such a request shall be in writing and will include the following:
  - (1) Identification of the product;
  - (2) Text of an applicable standard;
  - (3) Text of a test method, if not included in the applicable standard identified in paragraph (b)(2) of this section; and

Also basis of need
will include items
set out in Sec.7.5

  - (4) Basis of need for accrediting testing laboratories that serve the product identified in paragraph (b) (1) of this section.

and the

  - The basis will provide information relative to the items set out in Sec. 7.5 and will include, where appropriate, documentary evidence on such items as:

Number of labs
to be accredited

(i) the number of testing laboratories that is believed will want to be accredited to serve the product identified in paragraph (b)(1) of this section; and

Number of users
of testing labs

(ii) the number of users of testing laboratories that is believed will desire services of testing laboratories accredited to serve the product identified in paragraph (b)(1) of this section.

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| 7.4(c)<br>Secretary may ask for more information | o The Secretary may ask for more information to support a request made under paragraph (a) of this section if he feels it is necessary to do so. |
| Secretary may decline to act upon the request | o If on the basis of the information provided or because of the lack of resources, the Secretary is unable to justify the making of a preliminary finding of need, he will decline to act further on the request. |
| Secretary must respond in 10 working days | o The Secretary shall in that event notify the requester in writing within ten (10) working days after making a decision and shall state the reasons for so declining. |
| 7.4(d)<br>Should a request be made that may affect accreditation program of a Federal agency, Secretary shall seek views of such agency. | o If a request received under this section is believed to affect an existing or developing testing laboratory examination or accreditation program of a Federal regulatory agency, the Secretary shall seek from the head of such agency its views relative to the Secretary's making a preliminary finding of need. |
| Should the affected agency object in writing within 30 days, the Secretary shall cease further actions | o If within thirty (30) days after receipt of the Secretary's solicitation of views, or such extension of time as may be agreed to by the Secretary, the head of the affected Federal regulatory agency explains, in writing, his objections to the Secretary's making a preliminary finding of need, the Secretary shall cease to act further on the making of such finding. |
| And the Secretary shall notify the requester of such actions | o In that event, the Secretary shall notify the requestor of such objections and of his declination to act on the request pursuant to paragraph (c) of this section. |
| 7.4(e)<br>Should Secretary find that a need exists he will publicize in the Federal Register | o If, on the basis of the information provided to him, the Secretary finds that a need exists to accredit testing laboratories that serve a specific product, he shall publish a notice in the Federal Register indicating that such finding is a preliminary finding. |
| and provide at least 30 days for written comments | The notice shall include a statement as called for in Sec.7.5 as to the basis for the Secretary's finding and shall provide at least a thirty (30) day period for the submission of written comments thereon. |
| Should a public hearing be held, time for written comments shall be extended to hearing date | o In the event that a public hearing or hearings are held on this preliminary finding as authorized under paragraph (f) of this section, the period allowed for the submission of written comments shall be extended to the date on which such hearing or hearings are held. |
| 7.4(f)<br>Persons desiring to be heard shall notify the Secretary in 15 days | o Interested persons wanting to express their views in an informal hearing shall notify the Secretary of that desire within fifteen (15) days after the notice is published in the Federal Register. |
| If requested, informal hearings will be held for oral presentations | o Upon receipt by the Secretary of such request, informal public hearings shall be held so as to give all interested persons an opportunity for the oral presentation of data, views, or arguments, in addition to the opportunity to make written submissions. |

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| If appropriate hearings may be held at two places | o If deemed appropriate by the Secretary, such hearings may be held at two locations, one of which shall be east of the Mississippi River and the other west thereof. |
| with notice published in Federal Register | o Notice of such hearings shall be published in the Federal Register at least twenty (20) days in advance thereof. |
| | o A transcript shall be kept of any oral presentation. |
| All comments will be on file in the Commerce Building | ø (1) All written and oral comments will be filed in the Central Reference and Records Inspection Facility, Room 7068, Commerce Building, 14th Street between E Street and Constitution Avenue, N.W., Washington, D.C. 20230, and will be available for public inspection at that location. |
| 7.4(g)<br>By a notice in the Federal Register the Secretary shall make a final finding of need or shall withdraw his preliminary finding | o After evaluating the comments received, the Secretary shall publish a notice in the Federal Register making a final finding of need or withdrawing his preliminary finding of need to accredit testing laboratories that serve a specific product. |
| And shall state the basis for such finding | o The notice shall state the basis for the Secretary's final finding of need or for the withdrawal of his preliminary finding. |
| 7.4(h)<br>If notice sets out the final finding of need, it will include: | o The notice published under paragraph (g) of this section, if it sets out the Secretary's final finding of need, will also include: |
| (1) identification of product | ø (1) Identification of the product for which testing laboratories will be accredited to serve; |
| (2) identification of standards and test methods | ø (2) The identification of applicable standards, including the test methods involved; and |
| (3) statement that separate notice in Federal Register will advise that a NLACC will be formed or else an existing criteria committee will be used | ø (3) A statement that the Secretary is publishing simultaneously with this notice, a separate notice in the Federal Register advising that pursuant to the provisions of the Federal Advisory Committee Act (Pub. L. 92-463, dated October 6, 1972) the Secretary will form a National Laboratory Accreditation Criteria Committee pursuant to Sec. 7.6 or will utilize an existing Criteria Committee previously established under that section. |
| Such separate notice will state duties of Committee, its size and basis for selection of committee members. | ø Except where the Secretary utilizes an existing Criteria Committee such separate notice will outline the functions and duties of the Committee, its size, and the basis for selection of the members thereof. |

## 7.5 Statement of the basis for a preliminary finding of need.

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| Basis for preliminary finding of need are: | o The statement setting forth the basis for the preliminary finding of need referred to in Sec. 7.4(e) shall as a minimum address the following items: |
| 7.5(a)<br>The establishment of criteria must benefit public interest | o Whether the establishment of general or specific criteria and other conditions for accrediting testing laboratories that serve a specific product would benefit the public interest; |
| 7.5(b)<br>A National need extends beyond that served by any existing program | o Whether there is a national need to accredit testing laboratories for the specific product involved beyond that served by any existing laboratory accreditation programs in the public or private sector; |
| 7.5(c)<br>An existing product standard is deemed suitable by the Secretary | o Whether for the specific product involved, there is in existence a standard that is deemed by the Secretary as being of importance to commerce, consumer well-being, or the public health and safety; |
| 7.5(d)<br>Existing testing methodology is determined by the Secretary to be valid | o Whether there is in existence a valid testing methodology as determined by the Secretary for ascertaining conformity to to the standard of the specific product involved; and |
| 7.5(e)<br>Secretary determines that accreditation is feasible and practical | o Whether it is feasible and practical to accredit testing laboratories that serve the specific product involved. |

## 7.6 Establishment and functions of a National Laboratory Accreditation Criteria Committee.

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| 7.6(a)<br>When the Secretary establishes a Criteria Committee he will: | o The Secretary will establish a Criteria Committee and appoint the Chairman and members thereto following: |
| (1) publish a notice in the Federal Register according to Sec. 7.4(h)(3) | o (1) Publication of the separate Federal Register notice referred to in Sec. 7.4(h)(3) that announces the Secretary's intention to form a Criteria Committee, as distinguished from an announcement of intent to utilize an existing committee; and |
| (2) and file a charter setting forth purpose and nature | o (2) The filing of a charter setting forth the purpose and nature of the Criteria Committee. |
| 7.6(b)<br>Membership of Criteria Committee is chosen broadly from interested groups | o The membership of the Criteria Committee will be composed of employees of the Department of Commerce, other Federal agencies, and qualified representatives chosen from among producers, distributors, users, consumers, testing laboratories, academia, and general interest groups, including State and local governmental bodies and agencies affected by the Secretary's finding of need to accredit testing laboratories serving a specific product. |

Equitable balance of members that represent all interested groups

o The membership of each Criteria Committee shall be selected so as to provide an equitable balance that represents the interests affected by the Secretary's finding of need.

7.6(c) Criteria Committee shall be governed by the Federal Advisory Committee Act

o The establishment and functioning of each Criteria Committee formed and utilized by the Secretary under these procedures shall be governed by the applicable provisions of the Federal Advisory Committee Act, cited earlier herein.

Committee members may be paid per diem and travel expenses

o Persons selected to serve on a Criteria Committee may be paid travel expenses and per diem, provided authorized travel is involved.

7.6(d) Criteria Committee will develop and recommend criteria to the Secretary

o Upon formation of the Criteria Committee, the Secretary will request it to develop and recommend to him general and specific criteria to accredit testing laboratories that serve a specific product.

Secretary will define a time period for development of criteria

o The Secretary, in a written communication to the Chairman of the Committee, shall designate a time period for the development of general and specific criteria.

7.6(e) Criteria Committee may consult with other public and private parties to develop criteria

o When developing general or specific criteria, the Criteria Committee may, where it deems such action to be appropriate, consult with other interested public and private parties, including Federal, State and local agencies and private standards bodies.

and evidence of such consultation will be made a matter of public record.

o Exchanges of correspondence, memorandums and other evidence of such consultation will be made a matter of public record.

7.7 Development and recommendation of criteria for accrediting testing laboratories.

7.7(a) Secretary and Criteria Committee will be guided in Criteria development by factors such as these:

o The Secretary, and the Criteria Committee acting at the request of the Secretary, in developing general and specific criteria to accredit testing laboratories that serve a specific product shall consider factors such as:

ø (1) For general criteria pertaining to testing laboratories:

for general criteria

(i) Organization;
(ii) Staff:
(iii) Physical plant;
(iv) Operational processes;
(v) Control procedures;
(vi) Quality assurance; and
(vii) Professional and ethical business practices, as appropriate.

ø (2) For specific criteria pertaining to testing laboratories:

and for specific criteria

(i) Personnel and equipment qualifications required of the testing laboratory function;
(ii) Requirements applicable to proficiency sample programs;

(iii) Application requirements;
(iv) Initial and periodic examination and audit procedures; and
(v) Professional and technical qualifications of personnel who examine testing laboratories.

7.7(b)
Criteria in existing standards will be used when appropriate, but where none are found

- The general and specific criteria developed under this section for accrediting testing laboratories will be based upon criteria found in existing standards where such existing criteria are deemed appropriate.

Criteria Committee will undertake development of criteria

- Where appropriate existing criteria cannot be found, the Criteria Committee will, at the request of the Secretary, undertake to develop and recommend to him such appropriate general and specific criteria as may be needed.

7.7(c)
Instructions for making application shall be included in criteria together with conditions to be followed in the program:

- The criteria shall contain instructions for making application by testing laboratories serving the product involved and shall require that each testing laboratory that desires to participate in this program must agree to conditions that include but are not limited to the following:

(1) examination and audit

  - (1) Be examined and audited, initially and on a continuing basis;

(2) payment of fees

  - (2) Pay accreditation fees and charges; and

(3) limitation on advertising

  - (3) Avoid reference by itself and forbid others utilizing the services of an accredited testing laboratory from referencing its accredited status in consumer media and in product advertising or on product labels, containers and packaging or the contents therein.

7.7(d)
Accreditation by this program does not relieve laboratories from observing any existing statutes, or regulations

- The criteria shall contain a statement that compliance by testing laboratories with the general and specific criteria and other conditions established by the Secretary and which are accredited by him under these procedures shall in no way relieve such laboratories from the necessity of also observing and being in compliance with any existing Federal, State and local statutes, ordinances, and regulations that may be applicable to the operation of such laboratories, including consumer protection and anti-trust laws.

7.7(e)
This section does not:

- In carrying out the activities authorized by this section:

(1) prohibit accreditation solely on basis of organizational association or for being a foreign firm

  - (1) No action will be taken or criteria developed that would prohibit the accreditation of a testing laboratory solely on the basis of that laboratory's association or nonassociation with manufacturing, distributing or vending organizations, or because the testing laboratory is a foreign firm;

(2) provide for development of product standards or test methods

  - (2) No action will be taken under this program to develop a product standard or test method standard;

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| (3) establish procedures to modify a product standard or a test method standard | ø (3) No action will be taken under this program to modify a product standard or a test method standard where such a standard is in existence; |
| (4) propose to promulgate criteria considered to be impractical or contrary to the public interest | ø (4) No general or specific criteria will be promulgated unless compliance with such criteria and its implementation has been determined by the Secretary to be feasible and practical and not contrary to the public interest; and |
| (5) want or accept business data, trade secrets,etc. | ø (5) The Secretary, under this program, will not ask for or accept confidential business data, trade secrets or other proprietary information. |
| | 7.8 Publication of proposed criteria. |
| 7.8(a)<br>Criteria Committee shall forward its recommendations to the Secretary | o Upon its development of the general and specific criteria for accrediting testing laboratories under Sec. 7.7, the Criteria Committee shall forward its recommendations for such criteria to the Secretary for his consideration. |
| Secretary will publish it in Federal Register | o The Secretary, after consideration of such criteria will publish in the Federal Register a notice giving the complete text of the proposed general and specific criteria, |
| inviting written comments within forty-five (45)days | o and inviting any interested persons to submit written comments on such proposed criteria within forty-five (45) days after its publication in the Federal Register, unless another time limit is provided by the Secretary. |
| 7.8(b)<br>Request for a hearing can be made by interested persons within 15 days | o Interested persons wanting to express their views in an informal hearing shall notify the Secretary of that desire within fifteen (15) days after such proposed criteria are published in the Federal Register. |
| If requested, informal hearings will be held for oral presentation | o Upon receipt by the Secretary of such request, informal public hearings shall be held so as to give all interested persons an opportunity for the oral presentation of data, views, or arguments, in addition to the opportunity to make written submissions. |
| If appropriate, hearings may be held at two places | o If deemed appropriate by the Secretary, such hearings be held at two locations, one of which shall be east of the Mississippi River and the other west thereof. |
| with notice published in Federal Register | o Notice of such hearings shall be published in the Federal Register at least twenty (20) days in advance thereof. |
| written and oral comments will be filed and available for inspection | o A transcript will be kept of any oral presentation.<br>ø (1) All written and oral comments will be filed in the Central Reference and Records Inspection Facility, Room 7068, Commerce Building, 14th Street between E Street and Constitution Avenue NW., Washington, D.C. 20230, and will be available for public inspection at that location. |

7.8(c)
Criteria Committee will evaluate comments and make recommendations to the Secretary

- The Secretary upon receipt of all written and oral comments will request the Criteria Committee to conduct and return to him in writing, within a time period specified by the Secretary, its evaluation and recommendations with respect to such comments.

Secretary will act upon the Criteria Committee's recommendations in one of three alternatives:

- After considering the Criteria committee's evaluation and recommendations, the Secretary will prepare his evaluation and publish in the Federal Register a notice;

(1) to announce the final general and specific criteria

  - (1) Announcing the final general and specific criteria that testing laboratories must meet in order to be accredited and the date when such final criteria shall go into effect which shall not be less than thirty (30) days after the date of publication of such notice;

(2) to postpone action for further development

  - (2) Stating that the proposed general and specific criteria will be further developed before final publication; or

(3) to withdraw the criteria from consideration

  - (3) Withdrawing the proposed general and specific criteria from further consideration.

### 7.9 Coordination with Federal agencies.

7.9
Secretary will consult with interested Federal agencies for meaningful cooperation

- As a means of assuring effective and meaningful cooperation, input, and participation by those Federal agencies that have an interest in and may be impacted by the laboratory accreditation program carried out under these procedures, the Secretary shall undertake to communicate and consult with appropriate officials at policy making levels within those agencies.

Opportunities for Federal agency representatives to serve on Criteria Committees

- These coordination efforts will include opportunities for representatives designated by those agencies to serve on each Criteria Committee established by the Secretary in which those agencies have an interest.

### 7.10 Establishment of fees and charges.

7.10(a)
Secretary shall establish fees and charges for examining, accrediting and auditing

- The Secretary in conjunction with the use of the Working Capital Fund of the National Bureau of Standards, as authorized by section 12 of the Act of March 3, 1901, as amended (15 U.S.C. 278b), for this program shall establish fees and charges for examining, accrediting, and auditing testing laboratories.

Fees shall be calculated to maximize the self-sufficiency of the accrediting program

- The fees and charges established by the Secretary, which may be revised by him when he deems it appropriate to do so, shall be in amounts calculated to maximize the self-sufficiency of this program.

Notice in the Federal Register will give criteria of Sec. 7.8(a)

- A separate notice will be published in the Federal Register simultaneously with the notice of proposed general and specific criteria referred to in Sec. 7.8(a).

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| and a tentative schedule of fees and charges | o Such notice will set out a schedule of estimated fees and charges the Secretary proposes to establish. |
| so that public may evaluate criteria against fees charged | o The notice would be furnished for informational and guidance purposes only in order that the public may evaluate the proposed criteria in light of the expected fees to be charged. |
| 7.10(b)<br>Upon the announcement of final general and specific criteria a separate notice in Federal Register will list final schedule of fees | o At such time as the Secretary publishes the notice announcing the final general and specific criteria referred to in Sec. 7.8(c)(1), he shall simultaneously publish a separate notice in the Federal Register setting forth the final schedule of fees that will be charged testing laboratories that serve a specific product. |
| to become effective on date criteria becomes effective | o The effective date of such final schedule of fees shall be the same as the date on which the final general and specific criteria are to take effect. |
| 7.10(c)<br>Subsequent revisions to be published in Federal Register - to become effective in not less than thirty (30) days | o Revisions, if any, to the fees and charges established by the Secretary under paragraph (b) of this section shall be published in subsequent Federal Register notices and shall take effect not less than thirty (30) days after the date of publication of such notice. |
| | o Mention of such revisions shall also be published in the appropriate quarterly reports referred to in Sec. 7.17(a). |
| | 7.11 Participation of testing laboratories. |
| 7.11(a)<br>Each laboratory may initiate an application for accreditation | o Each testing laboratory serving a product for which final general and specific criteria have been promulgated under Sec. 7.8(c)(1), and desiring to be accredited under this program, will notify the Secretary of its desire pursuant to the provisions of such criteria. |
| 7.11(b)<br>Secretary will notify applicant and NBS of requirements and fees | o After receipt and evaluation of the testing laboratory's application and information contained therein, the Secretary shall, upon the acceptance thereof, notify the applicant testing laboratory and the National Bureau of Standards in writing of the specific applicable examination requirements for accreditation and the fees and charges for such examination and accreditation. |
| Rejected applicant may reapply after he has corrected deficiences | o If the application is not accepted, the Secretary shall notify the applicant testing laboratory of the reasons for rejection of its application, and such testing laboratory may reapply under Sec. 7.13(d) after correcting the deficiencies set out in the Secretary's notification of rejection. |
| Rejected applicant may request a hearing | o Alternatively, the applicant testing laboratory shall have thirty (30) days to request a hearing pursuant to 5 U.S.C. 556. |

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| Secretary's rejection would be stayed until the hearing | o | In the event, however, that the applicant testing laboratory requests a hearing within that thirty (30) day period the Secretary's rejection shall be stayed until the hearing held pursuant to 5 U.S.C. 556. |
| 7.11(c)<br>Applicant laboratories must meet general and specific criteria | o | A testing laboratory desiring to be accredited under this program to serve the product identified by the Secretary in his final finding of need under Sec. 7.4(g) in accordance with the standards and test methods identified by the Secretary in that finding must meet the general and specific criteria promulgated by him. |
| 7.11(d)<br>National Bureau of Standards, on behalf of Secretary, will arrange for examination of applicant laboratory | o | Upon receipt by the National Bureau of Standards of the applicant testing laboratory's written request for examination and of the fees and charges specified in paragraph (h) of this section, the National Bureau of Standards on behalf of the Secretary, will arrange for by contract or will itself conduct, the examination requirements of the Secretary. |
| National Bureau of Standards will assure that examiners possess qualification of Sec. 7.8(c)(1) | o | In all cases where testing laboratories are examined, the National Bureau of Standards will assure that the personnel used by the contractor or by the National Bureau of Standards possess the professional and technical qualifications set out in the specific criteria promulgated under Sec. 7.8(c)(1). |
| If NBS conducts examination, the resulting report will be sent to the Secretary | o | If the National Bureau of Standards conducts the examination, the resultant examination report will be forwarded to the Secretary. |
| If testing is prepared by contractor, NBS will review it before sending to Secretary | o | In cases where the examination report was prepared by a contractor, the National Bureau of Standards, before making payment thereunder or forwarding the report to the Secretary, will review the report to assure that the contract terms have been fulfilled. |
| 7.11(e)<br>Secretary will grant or propose to deny accreditation within 20 working days after receiving report. | o | The Secretary, after reviewing the examination report furnished under paragraph (d) of this section, will make a determination granting or proposing to deny accreditation to the applicant testing laboratory, not later than twenty (20) working days following the date on which the report is received by him. |
| or will notify applicant in writing with reason for delay | o | If the determination is not made within such time limit, the Secretary shall notify the applicant testing laboratory in writing of the reasons for the delay. |
| Secretary's determination of status will be given in writing | o | Upon making his determination, the Secretary will notify the testing laboratory in writing of its accreditation status. |
| and if he proposes to deny the accreditation he will state reasons | o | If the Secretary proposes to deny accreditation to an applicant testing laboratory, the notification will state the reasons for such proposed denial. |

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| 7.11(f) and the applicant shall have thirty (30) days from receipt of notice to request a hearing | o If an applicant testing laboratory is notified by the Secretary that he proposes to deny accreditation, the testing laboratory shall have thirty (30) days from the date of receipt of such notification to request a hearing under the provisions of 5 U.S.C. 556. |
| If appeal is not made in required period the Secretary's proposed denial will be made final in a written notification | o The Secretary's proposed denial shall become final through the issuance of a written decision to the applicant in the event that the applicant does not appeal such notification by the end of that thirty (30) day period. |
| However, if hearing is requested, proposed denial shall be stayed until hearing | o In the event, however, that the applicant testing laboratory requests a hearing within that thirty (30) day period, the Secretary's proposed denial shall be stayed until the hearing held pursuant to 5 U.S.C. 556. |
| | 7.12 Reference to accredited status. |
| 7.12 Advertising by the accredited laboratory is limited in scope | o Except as limited under Sec. 7.7(c)(3), a testing laboratory accredited under this program may use the following statement on its letterheads and in professional, technical and trade publications:<br>o "Accredited by the Department of Commerce, National Laboratory Accreditation Program for (appropriate wording as authorized by the Secretary's notification under Sec. 7.11(e))." |
| | 7.13 Revocation or termination of accreditation of a testing laboratory. |
| 7.13(a) Secretary may find cause to revoke the accreditation of a laboratory | o If the Secretary finds that a testing laboratory which he has previously accredited has violated the terms of its accreditation or the provisions of these procedures, he may, after consultation with such testing laboratory, notify that testing laboratory that he proposes to revoke its accreditation. |
| 7.13(b) If so notified by the Secretary such laboratory may request a hearing | o Upon receipt of a notice from the Secretary of the proposed revocation, which notice shall set forth the reasons for such proposed revocation, the accredited testing laboratory shall have thirty (30) days from the date of receipt of such notification to request a hearing under the provisions of 5 U.S.C. 556. |
| Revocation would become final should hearing not be requested in 30 days | o The Secretary's proposed revocation shall become final through the issuance of a written decision to the testing laboratory in the event that such testing laboratory does not appeal the proposed revocation within that thirty (30) day period. |
| Should a hearing be properly requested the proposed revocation shall be stayed | o In the event, however, that the accredited testing laboratory requests a hearing within that thirty (30) day period, the Secretary's proposed revocation shall be stayed until the hearing held pursuant to 5 U.S.C. 556. |

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| 7.13(c)<br>A laboratory may end participation with a written notice to the Secretary | o A testing laboratory may at any time terminate its participation and responsibilities under this program or withdraw its application for accreditation by giving written notice to the Secretary. |
| Receipt of notice would terminate processing of application | o Upon receipt by the Secretary of such notice, he shall terminate further processing of the testing laboratory's application for accreditation. |
| or terminate the accreditation | o If such testing laboratory has been accredited, the Secretary shall terminate that testing laboratory's accreditation. |
| when acknowledged by the Secretary | o The Secretary shall notify the testing laboratory that its accreditation has been terminated pursuant to its request. |
| 7.13(d)<br>A laboratory may reapply should accreditation be denied, revoked or terminated | o A testing laboratory whose application has been rejected or whose accreditation has been denied, revoked or terminated or which has withdrawn its application prior to being accredited may reapply for and be accredited if it meets the applicable general and specific criteria promulgated by the Secretary under Sec. 7.8(c)(1) and agrees also to meet the conditions set out under Sec. 7.7(c) and the provisions of Sec. 7.12. |
|  | 7.14 Cessation of accreditations. |
| 7.14(a)<br>Secretary may cease laboratory accreditation for a specific product | o The Secretary may cease the accreditation of testing laboratories that serve a specific product if he finds that there is no longer a need to accredit such laboratories. |
| Notice of preliminary finding in Federal Register | o An action to cease such accreditations shall commence with the issuance of a preliminary finding which shall be published in the Federal Register. |
| Shall address those items of Sec. 7.5 covered by original finding. | o Such notice shall set forth the Secretary's reasons for his preliminary finding and shall, as a minimum, address those relevant items listed in Sec. 7.5 which formed the basis for his original finding of need to accredit testing laboratories serving a specific product. |
| 7.14(b)<br>Minimum period of 60 days to submit written comments | o The notice published under paragraph (a) of this section shall provide at least a sixty (60) day period for the submission of written comments on the Secretary's preliminary finding. |
| Should public hearings be held written comments accepted up to hearing date | o In the event that a public hearing or hearings are held on this preliminary finding as authorized under paragraph (c) of this section, the period allowed for the submission of written comments shall be extended to the date on which such hearing or hearings are held. |
| 7.14(c)<br>Twenty (20) days allowed for the request for hearing | o Interested persons wanting to express their views in an informal hearing shall notify the secretary of that desire within twenty (20) days after the notice is published in the Federal Register. |

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| **Public hearings may be held to get views of all concerned** | o Upon receipt by the Secretary of such request, informal public hearings shall be held so as to give all interested persons an opportunity for the oral presentation of data, views, or arguments, in addition to the opportunity to make written submissions. |
| **Hearings may be held east and west of the Mississippi** | o If deemed appropriate by the Secretary, such hearings may be held at two locations, one of which shall be east of the Mississippi River and the other west thereof. |
| **Twenty (20) days advance notice in Federal Register** | o Notice of such hearings shall be published in the Federal Register at least twenty (20) days in advance thereof. |
| | o A transcript shall be kept of any oral presentation. |
| **all records of hearings will be available at Commerce Building** | (1) All written and oral comments will be filed in the Central Reference and Records Inspection Facility, Room 7068, Commerce Building, 14th Street between E Street and Constitution Avenue N.W., Washington, D.C. 20230, and will be available for public inspection at that location. |
| **7.14(d) Notice of Secretary's decision shall be in Federal Register** | o After evaluating the comments received, the Secretary shall publish a notice in the Federal Register making a final finding, or withdrawing his preliminary finding, that there is no longer a need to accredit testing laboratories that serve a specific product. |
| **together with basis for his decision** | o The notice shall state the basis for the Secretary's final finding or for the withdrawal of his preliminary finding. |
| **Cessation date shall be not less than 60 days after publication of notice** | o If the notice sets forth the Secretary's final finding that there is no longer a need to accredit testing laboratories that serve a specific product, such notice shall also state the effective date of such final finding which shall not be less that sixty (60) days after the publication of the notice. |
| **7.14(e) Cessation of accreditation affects all those previously accredited for a product.** | o If the Secretary ceases the accreditation of testing laboratories that serve a specific product as provided for in this section, he shall withdraw the accreditation previously issued to all those testing laboratories serving the same specific product. |
| **Such accredited laboratory may seek to serve another product** | o Any testing laboratory whose accreditation to serve a specific product has been withdrawn by the Secretary under this subsection may seek to be accredited to serve a different specific product under these procedures, |
| **and may be accredited by meeting provisions of Secs. 7.7(c), 7.8(c)1 and 7.12** | o and may be so accredited if it meets the general and specific criteria promulgated by the Secretary under Sec. 7.8(c)(1) that are applicable to that different specific product and if it agrees also to meet the conditions set out under Sec. 7.7(c) and the provisions of Sec. 7.12. |
| **7.14(f) Accreditation may be reinstituted by procedures of Sec. 7.4** | o The Secretary may reinstitute the accreditation of testing laboratories that serve a specific product which he previously ceased accrediting under this section. |

- In that event he shall follow the same procedures set out under Sec. 7.4 relative to the finding of need to accredit testing laboratories that serve a specific product.

7.15 Refund of fees and charges.

7.15(a)
Some fees will be refunded should the laboratory withdraw its application for accreditation

- If a testing laboratory withdraws its application for accreditation after it has submitted the required examination fees and provides written notice to the Secretary of such withdrawal prior to the issuance of an accreditation or the denial thereof, the testing laboratory will be refunded such fees except for the application fee, if any, and for any other costs that have been incurred relative to its application.

7.15(b)
No refunds made when laboratory terminates participation

- If a testing laboratory terminates its participation and responsibilities under this program at any time after it has been accredited or after it has been notified by the Secretary that it is not being accredited, no part of the fees and charges paid by the testing laboratory will be refunded.

7.15(c)
No refunds made when accreditation is revoked under Sec. 7.13

- If the accreditation of a testing laboratory is revoked by the Secretary under Sec. 7.13, no part of the fees and charges paid by the testing laboratory will be refunded.

7.15(d)
Some fees will be refunded when the accreditation ceases as in Sec. 7.14

- If the Secretary ceases the accreditation of testing laboratories that serve a specific product under Sec. 7.14 and withdraws the accreditation of a testing laboratory to test a specific product under that section, such testing laboratory will be refunded the unexpended part of the examination fees or charges paid by such testing laboratory to maintain its accredited status under this program:

  PROVIDED, HOWEVER, That no such testing laboratory will be refunded its original application fee, if any, to be accredited to serve a specific product.

7.16 Amendment or revision of criteria.

7.16
Provisions are made for amendments or revisions to previously promulgated criteria

- The Secretary, or a Criteria Committee acting at the request of the Secretary, may undertake the development of amendments or revisions of any applicable general or specific criteria previously promulgated by the Secretary by following the same procedures pertaining to the original development of such criteria.

### 7.17 User education and reports.

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| 7.17(a)<br>Secretary will publish a quarterly report of actions involving each specific product | o For each specific product for which the Secretary has made a final finding under these procedures that a need exists to accredit testing laboratories that serve such product, he will publish a quarterly report noting all action taken by him regarding such matters as accreditations, revocations, the establishment of fees and charges, the promulgation of general and specific criteria and any amendments or revisions to such criteria. |
| Such report to state clearly that accreditation does not relieve the laboratories from any legal responsibilities | o Such publications shall clearly state that testing laboratories accredited by the Secretary under these procedures are in no manner immune from the necessity of being in compliance with all legal obligations and responsibilities imposed by existing Federal, State, and local laws, ordinances, and regulations, including those related to consumer protection and antitrust prohibitions. |
| 7.17(b)<br>Secretary's annual report shall list all laboratories accredited during the year | o The Secretary will also prepare an annual report summarizing all activities carried out under these procedures which shall include a listing of all testing laboratories accredited by the Secretary during the year to which the annual report relates. |
| 7.17(c)<br>Secretary shall report monthly in the Federal Register<br>all actions involving status change | o As a means of giving prompt notice to the public of accreditation actions taken by the Secretary, he shall, in addition to the reports called for under this section, publish in the Federal Register all actions taken by him during the preceding month which grant, revoke, terminate or result in the withdrawal of the accreditation of a testing laboratory. |
| with name and address of laboratories concerned | o Such notice shall include the name and address of the testing laboratory concerned, and a brief explanation of the action taken by the Secretary with respect to that laboratory. |

### 7.18 Support function.

| | |
|---|---|
| Secretary shall provide necessary support | o The Secretary shall make provisions for administrative and technical support and staff services as may be needed to carry out this program. |

## 10.4 Hose Connection Vacuum Breaker Tests at NBS

A test was conducted to see how the HCVB would respond to simultaneous back-siphonage and back pressure (due to garden hose elevation) when the check valve was fouled with a wire in the manner presented in ASSE standard No. 1011 for the back-siphonage test method.

### 10.4.1 Test Procedure and Results

The basic test procedure was as follows and as depicted in figure 5:

(a) Fill Pail "A" to some level (measured from the floor) as shown in setup #1, figure 5. (Pail "A" simulates a contaminated source - swimming pool).

(b) Weigh Pail "B" (tare weight) on weighing platform shown in figure 6, Appendix 10.5 (Water flows out of the vent ports down the outside of the hose and into Pail "B").

(c) Open spring loaded hose nozzle submerged to bottom of Pail "A".

(d) Open vacuum valve "C" (make sure Pail "B" is dry). The purpose of Pail "B" is to collect vent port discharge.

(e) Simultaneously open quick-closing valve "D" and start time interval recorder.

(f) Read vacuum manometer and record vacuum (absolute value).

(g) When the sight glass is half full with water, shut valve "D" and simultaneously stop time interval recorder. (Water collected in the sight glass is backflow).

(h) Weigh Pail "B" to get weight of water plus weight of bucket.

(i) Remove the hose from HCVB and blow water (compressed air) from sight glass through HCVB into a graduated cylinder (milliliters). Record the volume of water as milliliters of back-siphonage.

For each setup shown in figure 5, make triplicate runs.

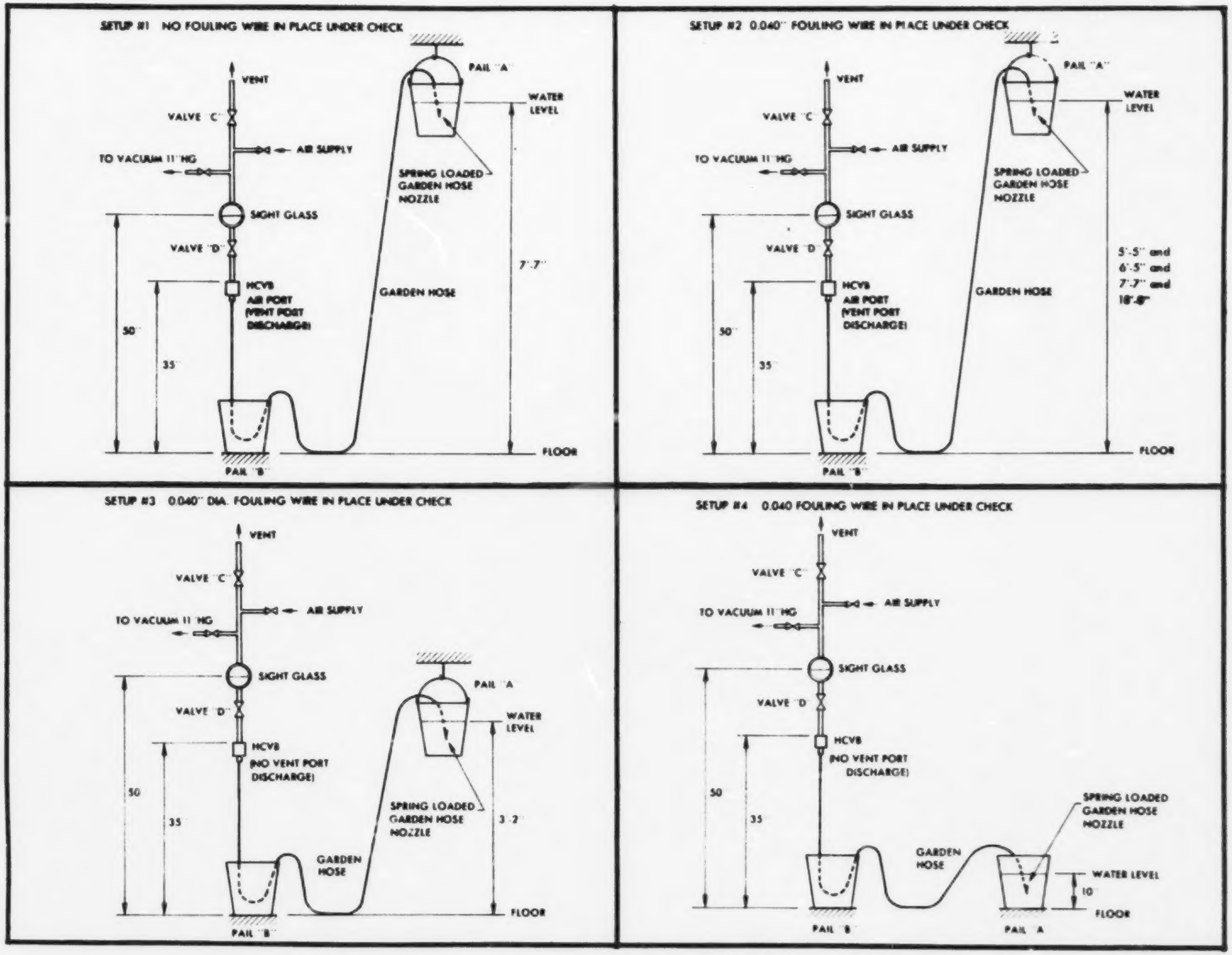
SETUP #1 NO FOULING WIRE IN PLACE UNDER CHECK
VENT
VALVE "C"
TO VACUUM 11"HG
AIR SUPPLY
SIGHT GLASS
VALVE "D"
HCVB
AIR PORT
(VENT PORT DISCHARGE)
50"
35"
PAIL "B"
GARDEN HOSE
PAIL "A"
WATER LEVEL
SPRING LOADED GARDEN HOSE NOZZLE
7'-7"
FLOOR
SETUP #2 0.040" FOULING WIRE IN PLACE UNDER CHECK
VENT
VALVE "C"
TO VACUUM 11"HG
AIR SUPPLY
SIGHT GLASS
VALVE "D"
HCVB
AIR PORT
(VENT PORT DISCHARGE)
50"
35"
PAIL "B"
GARDEN HOSE
PAIL "A"
WATER LEVEL
SPRING LOADED GARDEN HOSE NOZZLE
5'-5" and
6'-5" and
7'-7" and
18'-8"
FLOOR
SETUP #3 0.040" DIA. FOULING WIRE IN PLACE UNDER CHECK
VENT
VALVE "C"
TO VACUUM 11"HG
AIR SUPPLY
SIGHT GLASS
VALVE "D"
HCVB
(NO VENT PORT DISCHARGE)
50
35
PAIL "B"
GARDEN HOSE
PAIL "A"
WATER LEVEL
SPRING LOADED GARDEN HOSE NOZZLE
3'-2"
FLOOR
SETUP #4 0.040 FOULING WIRE IN PLACE UNDER CHECK
VENT
VALVE "C"
TO VACUUM 11"HG
AIR SUPPLY
SIGHT GLASS
VALVE "D"
HCVB
(NO VENT PORT DISCHARGE)
50
35
PAIL "B"
GARDEN HOSE
SPRING LOADED GARDEN HOSE NOZZLE
WATER LEVEL
10"
FLOOR
PAIL "A"

Figure 5. Backsiphonage/Back Pressure Tests of Hose-Connection Vacuum Breaker with Fouled Check

The average results are presented in Table 12. The average vacuum was 11.7 centimeters of mercury, absolute. The above average rate results were quite repeatable even though vacuum fluctuations of about ± 2 cm of mercury occurred sporadically throughout each run. The last observed vacuum reading before closing valve "D" was recorded as the running vacuum and these values were averaged. This variation is judged to be normally caused by water movement through the atmospheric vents of the HCVB. Water movement being somewhat variable since air is attempting to enter the vents simultaneously as water tends to escape.

### 10.4.2 Discussion of Results

Even though vacuum varied somewhat, the back-siphonage rate tended to remain quite constant. The volumes collected generally were several hundred milliliters and these volumes tended to be repeatable within ± 20 milliliters during any set of three runs for a given setup. Out of fifteen runs only one run was off by ± 50 milliliters. The back-siphonage rate did not vary appreciably with increasing back pressure condition. The device is designed to relieve back-pressure through the ports and data shows that it does this quite effectively. Although back-siphonage rate remained relatively constant with increasing back pressure, the vent discharge increased considerably as back pressure head was increased. A constant back-siphonage rate indicated that back pressure at the HCVB must be relatively constant regardless of the back pressure head potential imposed by the elevated hose.

TABLE 12 HCVB TEST RESULTS

| TEST SETUP # | FOULING WIRE | ELEVATION OF PAIL "A" | BACK-SIPHONAGE RATE - gpm | ATMOSPHERIC VENT PORT DISCHARGE RATE - gpm |
|---|---|---|---|---|
| 1 | none | 7'7" | 0 | not measured |
| 2 | 0.04" Dia. Wire under HCVB Check | 5'5" | 0.22 | 0.18 |
| " | " | 6'5" | 0.22 | 0.22 |
| " | " | 7'7" | 0.22 | 0.34 |
| " | " | 18' | 0.24 | 0.88 |
| 3 | " | 3'2" | 0 | trace (not measured) |
| 4 | " | 10" | 0 | 0 |

### 10.5 Reduced-Pressure Backflow Prevention Device Tests at NBS

A test was conducted to determine if the RPBD would allow back-siphonage, when checks were fouled with wires in the manner used for testing vacuum breakers.

### 10.5.1 Test Procedure and Results

The basic test procedure was as follows:

(a) Mount the device in its normal operating position as recommended by the manufacturer, using test setup shown in Figure 6.

(b) Apply water pressure to the device and conduct the three tests described in AWWA publication No. S106, pages 21 and 22 [34] to determine that the checks are tight and that the relief valve is functioning according to specifications.

(c) With check valve seats fouled with 0.042 inch diameter wire, apply vacuum to the inlet and back-pressure to the outlet of the device simultaneously. (Down stream check appears to be open more than 0.042 inches because of its design).

(d) Measure zone pressure in inches of water column and record.

(e) Read back pressure at pressure gage P and record reading.

(f) With start of the run referenced to the initial application of vacuum, time the run for an interval of 60 to 70 seconds and close inlet and outlet valves simultaneously.

(g) Measure the volume of backflow (back-siphonage) collected during the time interval and also the weight of water in the zone discharge. Calculate flow rates in gpm.

(h) Tabulate results as follows:

| RUN # | VOLUME OF BACK-SIPHONAGE COLLECTED - ml | TIME TO COLLECT - Sec. | BACK-SIPHONAGE RATE - gpm |
|---|---|---|---|
| 1 | 130 | 60 | 0.034 |
| 2 | 125 | 70 | 0.028 |
| 3 | 110 | 70 | 0.025 |

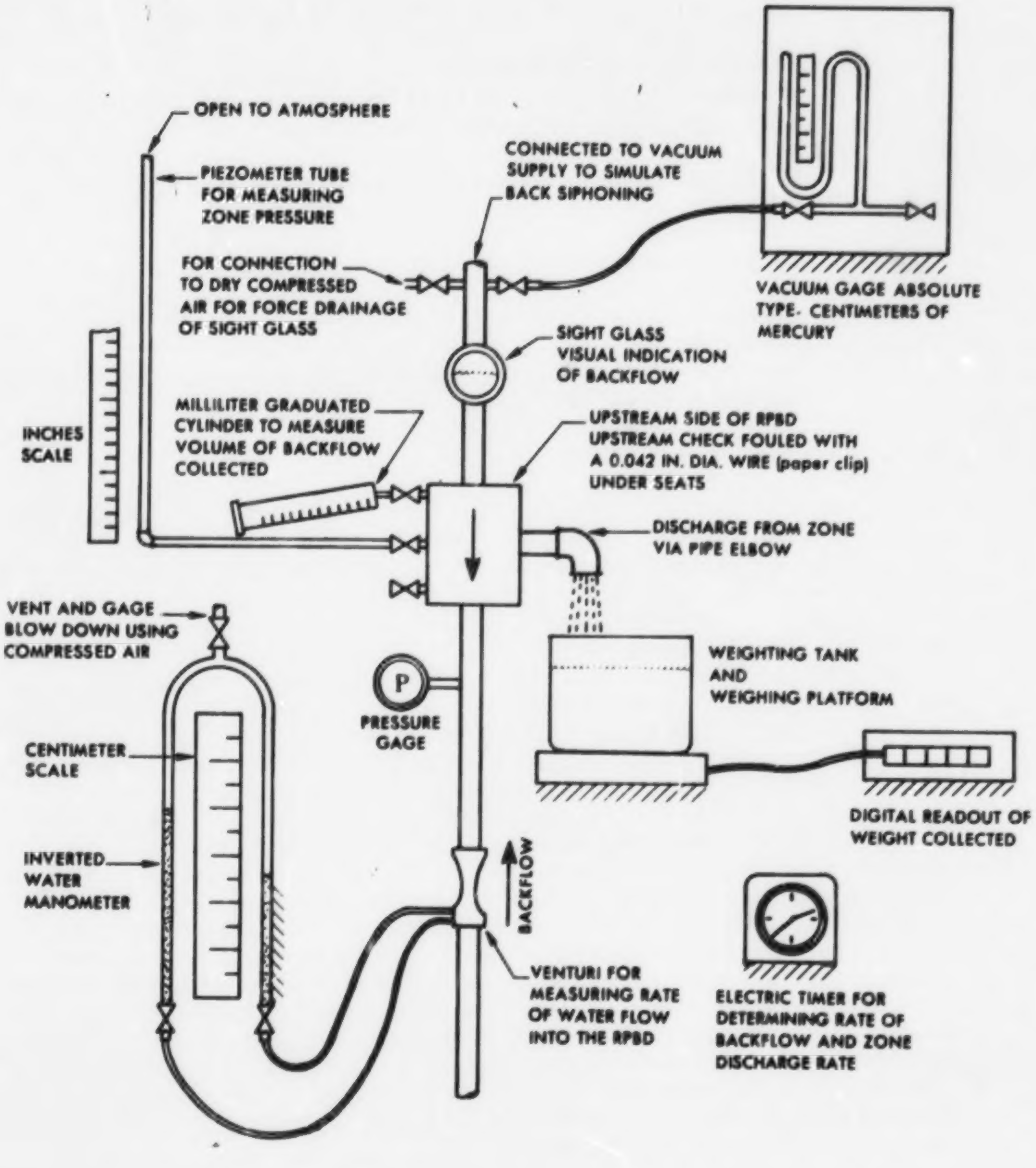
OPEN TO ATMOSPHERE
PIEZOMETER TUBE FOR MEASURING ZONE PRESSURE
CONNECTED TO VACUUM SUPPLY TO SIMULATE BACK SIPHONING
FOR CONNECTION TO DRY COMPRESSED AIR FOR FORCE DRAINAGE OF SIGHT GLASS
VACUUM GAGE ABSOLUTE TYPE- CENTIMETERS OF MERCURY
SIGHT GLASS VISUAL INDICATION OF BACKFLOW
INCHES SCALE
MILLILITER GRADUATED CYLINDER TO MEASURE VOLUME OF BACKFLOW COLLECTED
UPSTREAM SIDE OF RPBD UPSTREAM CHECK FOULED WITH A 0.042 IN. DIA. WIRE (paper clip) UNDER SEATS
DISCHARGE FROM ZONE VIA PIPE ELBOW
VENT AND GAGE BLOW DOWN USING COMPRESSED AIR
WEIGHTING TANK AND WEIGHING PLATFORM
P
PRESSURE GAGE
CENTIMETER SCALE
DIGITAL READOUT OF WEIGHT COLLECTED
INVERTED WATER MANOMETER
BACKFLOW
VENTURI FOR MEASURING RATE OF WATER FLOW INTO THE RPBD
ELECTRIC TIMER FOR DETERMINING RATE OF BACKFLOW AND ZONE DISCHARGE RATE

Figure 6. A Diagram of Apparatus Used in the Testing of the Reduced-Pressure Backflow Prevention Device.

The average of three (3) runs of data are as follows:

(a) 1.85 gpm backflow rate (also zone discharge rate for all practical purposes). Well below the rate specified in the standards for a 3/4" safe RPBD.

(b) 0.029 gpm back-siphonage rate (rate into inlet of the device).

(c) Zone pressure one (1) inch of water column.

(d) Backpressure 1.31 psig (36 1/4" head).

(e) Vacuum, 11 centimeters of mercury absolute (at inlet during back-siphonage).

### 10.5.2 Discussion of Results

The relatively low backflow rate appeared close to the cutoff condition when backflow would not occur (not exactly defined since such information would serve no useful purpose at this time because the purpose was merely to test at some reasonable condition). The rubber check material tended to seal itself around the fouling wire and back-siphonage rate decreased with time. Unfortunately, it was beyond the scope of this effort to investigate this phenomenon. It was noticed that backflow rate tended to fall off with time after initial installation of the fouling wires. The preceding backflow data illustrates a slight change and trend during the runs. The three runs were taken in about one hour (approximately 20 min./run).

After the device had been idle for several weeks with fouling wires in place, it was noticed that only about 10 ml was collected during a one minute period. The short term effect (one hour) appears to be the seating of the soft rubber upstream check valve material around the wire (self repairing, sealing tendency). The long term effect (several weeks) appears to be the self repairing tendency plus the effect of wire diameter reduction caused by corrosion. After several weeks the wire diameter was reduced to about 0.020 inch diameter in that portion under the seat of the upstream check. It was not determined if complete sealing would result in time due to the seating effect. Some reduction in backflow rate must have occurred due to reduction in wire diameter.

The flow rates imposed on the zone were well below the value set in the RPBD standards (five gpm). Zone pressure with or without backsiphonage were well below the 1.5 psig maximum allowed by the RPBD standards (appeared to be the same with or without vacuum at inlet to the RPBD). Zone pressures and flow rates were checked as follows:

| ZONE FLOW RATE | BACK PRESSURE | ZONE PRESSURE |
|---|---|---|
| 1.85 gpm | 1.3 psig | 1" of water |
| 4.27 | 2.5 | 2.5" of water |
| 4.88 | 5.0 | 4.0" of water |

At the end of the test, the fouling wires were removed and the device tested in the usual field test manner using a differential gage .8/ The test was conducted with 60 psig of water pressure. The opening differential pressure of the relief valve was 6.5 psig which was the same as that obtained at the beginning of the test. This test and zone pressure tests demonstrated that the device was operating in a satisfactory manner.

The reason why backflow took place is simply that the zone was full of water at a pressure superior to that at the inlet, and the inlet was separated from the zone by the leaking check which allowed water to flow from the high pressure zone into the low pressure inlet. One of the basic problems is that water flowing from the relief valve port blocks air that tends to enter the zone to vent the vacuum in the inlet. In other words, this RPBD acts like a submerged vacuum breaker. If it had adequate zone shape and configuration with independent zone venting and drainage such that the air inlet was not submerged and the upstream check were exposed only to the entering air during backsiphonage, backflow of the liquid would be prevented.

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8/ The differential gage was a special manufactured kit especially designed and sold for use with RPBD.

## 10.6 Analysis of Test Methods in ASSE Standards for Backflow Prevention Devices

While seeking a means of evaluating the tests methods that apply to existing standards for backflow protection devices, it was noted that the recent ASSE Standards could be analyzed into:

(a) Test requirement

(b) Test Setup and Preparation for Testing

(c) Test Procedure

(d) Observations, Records, and Computations

(e) Basis for Rejection of Device

The results of such analyses to the ASSE Standards 1001, 1002, 1011, 1012, 1013, 1015 and 1020 are documented herewith on tables 13 through 19. A uniformity of style has become established with the more recent output. The uniformity of style or format is sharply defined in table 20 wherein the numerical sequence of paragraph of ASSE 1013 were matched with comparable subject matter (where possible) to be found in ASSE 1001, 1011, 1012, and 1015. Such analysis is expected to be helpful in the development of criteria.

Table 13 Matrix Arrangement of Essential Contents of Section 3, Performance Requirements, and Section 4, Performance Tests, Contained in A.S.S.E. Standard 1001 "Standards and Test Procedures for Pipe-Applied Atmospheric Type Vacuum Breakers," Dated October 1970.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 4.1 Nontoxic Certification | 3.1 Material Toxicity<br>The entire assembly shall be certified by the manufacturer to be of nontoxic materials, when used with potable water. | | A device submitted for testing shall be accompanied by a notarized certification from the manufacturer stating that all of the materials in the device are nontoxic when used in conjunction with potable water. | | |
| 4.2 Positive Pressure | 3.2.1 Cold Water Devices<br>Devices for cold water supply lines only, shall withstand a hydrostatic working pressure of 125 psi. over a working temperature range from 32°F up to and including 110°F without leaking. | The device to be tested shall be mounted in its normal position. A control valve shall be mounted in the outlet end of the device and a pressure tap shall be provided in the inlet opening. A pressure gage, with a scale spread no greater than 0-300 psi shall be fitted into the pressure tap. The inlet supply pipe shall be connected to a water supply line whose pressure can be raised to 125 psi. | Water shall be allowed to flow freely through the device. Then the control valve at the outlet end of the device shall be closed and the water pressure in the test assembly allowed to rise to 125 psi, plus or minus 2 psi. This pressure shall be maintained for 10 minutes ......<br>The test described above shall be repeated three times ........... | ......during which the device shall be examined for evidence of any leaks or structural deformation. | ......and any evidence of leakage shall be cause for rejection of the device. Distortion of the device that renders it incapable of passing any of the succeeding tests listed shall be cause for rejection |
| | 3.2.2 Hot or Cold Water Devices<br>Devices for use with either hot or cold water shall withstand a hydrostatic working pressure of 125 psi over a working temperature range from 32°F up to 212°F, without leaking. | | The above described test shall be performed with water held at 32°F, plus 5°F, minus 0°F, and with water held at 110°F, plus or minus 5°F, for those vacuum breakers designed for cold water use. The device shall be tested three times at each water temperature.<br>The above described test shall be performed with water held at 32°F, plus 5°F minus 0°F, and with water held at 212°F, plus 0°F minus 5°F, for those vacuum breakers designed for hot water use. The device shall be tested three times at each water temperature. The above test temperature and pressure shall be held within the tolerance listed for the duration of the test. | | |

Table 13 (Continued)Matrix Arrangement of Essential Contents of Section 3, Performance Requirements, and Section 4, Performance Tests, Contained in A.S.S.E. Standard 1001 "Standards and Test Procedures for Pipe-Applied Atmospheric Type Vacuum Breakers", Dated October 1970.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 4.3<br>Air Port Shield | Sec. 3.3<br>Air ports of vacuum breakers shall be shielded so as to minimize the probability of port fouling, air port shields shall extend down around the body of the device to the lowest portion of the air ports, and shall maintain a minimum 3/16" clearance between the inner lower edge of the shield and the surface plane of the air ports. | | | Air port shields shall be examined to determine if they extend down to the bottom of lowest air port opening. Clearances between the shield and the body of the device shall be measured to determine if an unobstructed 3/16" air passageway is maintained. | |
| 4.4<br>Air Flow Test | Sec. 3.4<br>The size and positioning of the air ports shall be effective in admitting a volume rate of air flow through the air ports into the discharge outlet of the device equal to or greater than the volume rate of air flow obtainable through the inlet water passageway of the device into the discharge outlet under conditions of equal vacuum applications. | .....to compare the effective through-way area from its water inlet to outlet in relation to its available internal air relief area.....as follows:<br>(1) Install the device in the normal operating position with the check or moving member held fully open and the air valve held closed. Connect the discharge outlet of the device by means of a 12" length of reamed corresponding size piping to an adequately sized vacuum tank capable of providing at least a 10 second air flow, and with the inlet open and a 12" reamed nipple of corresponding size threaded into the inlet (Fig. 1)........ | .....(Fig. 1) dissipate the vacuum in the tank from 25" to 5" of mercury through the check valve orifice by operating a quick-opening valve, timing the operation. See Fig. 1 and 6.<br>(2) With the discharge outlet still connected to the vacuum tank and the inlet check held in a closed position, hold the air valve open and dissipate the vacuum in the tank from 25" to 5" of mercury in the same manner through the air port or ports, timing the operation. | (3) The time for (2) shall be equal to or less than (1) based on the average result of not less than 3 test runs, indicating that the openings to the atmosphere is (are) equal to or greater than the effective water way through the device. | |

*Note: Figure numbers refer to those in ASSE 1001, not to figures in this report.

Table 13 (Continued) Matrix Arrangement of Essential Contents of Section 3, Performance Requirements, and Section 4, Performance Tests, Contained in A.S.S.E. Standard 1001 "Standards and Test Procedures for Pipe-Applied Atmospheric Type Vacuum Breakers," Dated October 1970.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 4.5 Water Rise Test | Sec. 3.6<br>The device shall not permit a water rise of more than 3" in a tube connected to the outlet end of the vacuum breaker even when the check member is held off its seat (as required in Sec. 4.5) during varied vacuum applications ranging from 0 to 25 inches of mercury (corrected for sea level pressure). | Sec. 4.5<br>The device shall be subjected to tests to determine the internal reverse flow leakage should the check(s) or moving member(s) of its seat become scored or fouled with a foreign substance on the seating area. The test apparatus shall conform to that shown in Fig. 6.<br>(1) To foul the check(s) or moving member(s) of the device, a wire or spacer test shall be applied, using a minimum sized wire .032" in diameter for devices having a nominal pipe size of 1/8", 1/4", [illegible]/8", and 1/2". For devices having a nominal inlet pipe size of 3/4" or larger, the diameter of the test wire shall be increased in increments of .008 for each 1/4" increase in diameter of nominal inlet pipe size. See Fig.2.<br>(Test wires shall be furnished by the manufacturer shaped or formed to fit the contour of the seal or tube. The shaped test wires submitted must be in conformance with the table in Fig. 2)<br>(2) This wire shall be placed in the lower quadrant of a suspended check(s) opposite the hinge(s) or point(s) of suspension (See Fig. 3). When testing a device in which the<br>(Continued on next page) | (4) The device shall then be subjected to tests, as described below involving (a) sustained vacuum, (b) intermittent vacuum, (c) effects of instantaneously applied vacuum, and (d) gradually increasing and decreasing vacuums to establish creep.<br>The following tests shall be repeated to obtain five successive measurments under each set of conditions:<br>(a) Apply a constant vacuum of at least 25" of mercury for a period of at least 30 seconds.<br>(b) Apply intermittent vacuums of 2, 5, 10, 15, and 25 inches of mercury. Each application shall be for 5 seconds on and 5 seconds off.<br>(c) First, slowly apply a vacuum increasing at a uniform rate from 0" to 25" of mercury. Second, slowly apply a vacuum decreasing at a uniform rate from 25" to 0" of mercury. | NOTE: In tests (a) through (d) vacuum levels are sea-level values; at high altitudes, appropriate corrections should be made so as to produce the same vacuum in terms of fractional parts of an atmosphere at th the higher altitude<br>(5) Observe the elevation to which the water surface rises in the transparent tube beneath the vacuum breaker in each test described in Par. 4.5 (4). | If the water rise exceeds 3" in any one of the observations, the unit being tested is not acceptable. |

Table 13 (Continued) Matrix Arrangement of Essential Contents of Section 3, Performance Requirements, and Section 4, Performance Tests, Contained in A.S.S.E. Standard 1001 "Standards and Test Procedures for Pipe-Applied Atmospheric Type Vacuum Breakers", Dated October 1970.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| | | Sec. 4.5 Continued from previous page.<br>check member(s) is (are) not hinged, but moves vertically, the wire or spacer shall be placed at a single point of suspension on the seating area, on center line in the direction of the outlet port, as illustrated (See Fig. 4 and 5). Devices having other types of moving parts shall have said parts spaced or defaced to accomplish the intent of this section.<br>(3) The device shall be installed in its normal operating position; the check(s) member(s) shall be fouled with the proper size wire or spacer in the proper position or by defacement depending on the type of check member(s) and the inlet of the device connected to a vacuum line. A transparent "sight" tube shall be connected to the outlet of the device and the lower end of such tube submerged in water to within 6" of the bottom of CIL point of the device. | | | |

Table 14 Matrix Arrangement of Essential Contents of Section V, Test Procedures, Contained in A.S.S.E. Standard No. 1002 "Standards and Test Procedures for Water Closet Flush Tank Ball Cocks", Dated October 1964, Revised October 1968.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| VA-1<br>VA-2<br>II-2<br>II-4<br>Positive Pressure | II-2<br>All parts up to and including the water supply valve shall withstand 125 P. S. I. working pressure. Those parts of the unit on the discharge side of the water supply valve shall be designed to withstand the resultant flow pressure.<br>II-4<br>The device shall perform satisfactorily when used with water temperatures up to and including 110° Fahrenheit. | VA-2<br>When installed in a water closet flush tank and actuated by its designed closing mechanism, the valve shall terminate the flow of water through the ball cock at 125 P. S. I. and shall reopen as the content of the tank is being discharged. | VA-1<br>The ball cock shall be totally immersed in water at 110° Fahrenheit for a minimum period of four hours. During the entire period the valve mechanism shall be subjected to continuous water pressure at 100 P. S. I. | | No deformation of the ball cock shall be evident. |
| | II-3<br>When fully open the valve of the device shall deliver a minimum of 1 1/2 G. P. M. at 8 P. S. I. flow pressure. In order to conserve water the refill mechanism shall be designed in such a manner that the amount of refill water supplied to the closet bowl shall be commensurate with the type of bowl. | The ball cock unit shall be installed in its normal operating position and connected to a water supply in which the flow pressure may be maintained at 8 P. S. I. | With the ball cock water supply valve(s) fully open, the water discharged from both the tank fill tube or port and the refill tube shall be collected in a suitable vessel so that the total discharge from the unit may be measured. | The flow rate shall be determined by averaging the results of not less than three tests.<br>__NOTE__: The test operator shall observe that under all conditions of flow (8 through 125 P. S. I.) the device shall discharge no water outside the closet flush tank. | |
| | | | | | |

Table 14 (Continued) Matrix Arrangement of Essential Contents of Section V. Test Procedures, Contained in A.S.S.E. Standard No. 1002 "Standards and Test Procedures for Water Closet Flush Tank Ball Cocks", Dated October 1964, Revised October 1968.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| VB-1<br>VB-2<br>VB-3<br>Test for Vacuum Breaker Equipped with Ball Cocks<br>VB-4<br>VB-5<br>VB-6 | VB-1<br>The unit shall be subjected to tests to determine the internal reverse flow leakage should the vacuum breaker check(s) or moving member(s) or its seat become scored or fouled. This test will govern the installed position of the ball cock within the closet flush tank. | VB-2<br>To foul the check(s) or moving member(s) of the vacuum breaking device, a wire or spacer test shall be applied using a minimum dimension of 0.032".<br>VB-3<br>The wire spacer shall be placed in the lower quadrant of a suspended check(s), opposite the hinge(s) or point(s) of suspension. If it is a device in which the check member(s) is(are) not hinged but move vertically, the wire spacer shall be placed at a single point of suspension on the seating area on a center line in the direction of the outlet port, as illustrated. (See Fig. 2, Page 5).<br>NOTE: The object of the wire or spacer is to create a condition of defect, malfunction, or leakage due to wear or to the presence of scale, chips, and other foreign items normally encountered in potable water distribution systems. Therefore, the above procedure of spacing may require modification with certain unusual designs, particularly with ball cocks using diaphragms or checking members of elastomeric materials.<br>In all cases, however, the water supply valve must be held fully open and the checking member of the vacuum breaking device fouled to cause a leakage condition equivalent to that prescribed in V-B2 above. Any supplementary checking mechanism upstream from the anti-siphon device shall be held fully open. | VB-5<br>With the tank water level lowered 1/8" below the vacuum breaker air port(s) the unit shall then be subjected to variable vacuums of 25" to 0" of mercury and 0" to 25" of mercury both by surge application in increments not to exceed 5" and by gradual application to determine line "BB", the elevation at which back siphonage ceases as the test tank water level is lowered; and line "AA", the elevation at which back siphonage begins as the level is raised. (See Fig. 3, Page 7). While these two lines may coincide, should they differ, whichever line proves to be the lower shall be determined as the critical level (C. L.), of the unit and shall govern its installed position. The elevation of the (C. L.), so determined, shall be rechecked after the addition of sufficient dye to the water in the tank to give it a vivid color. The water level shall then be slowly raised by increments of not more than 1/16" until colored water appears in the "sight glass" indicating back siphonage and any necessary downward adjustment of the previously determined critical level. | | |

Table 14 (Continued) Matrix Arrangement of Essential Contents of Section V. Test Procedures, Contained in A.S.S.E. Standard No. 1002 "Standards and Test Procedures for Water Closet Flush Tank Ball Cocks", Dated October 1964, Revised October 1968.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| | | VB-4<br>The unit shall be installed in its normal operating position in a test tank having transparent walls. The check(s) member(s) shall be fouled with an 0.032" wire or spacer placed in the proper position or by defacement depending on the type of check(s) member(s) and the water supply inlet of the unit connected through a transparent tube or sight glass to a vacuum line. The shutoff valve of the unit shall be held in a fully open position and the refill tube positioned outside the overflow tube and its discharge end submerged. The tank shall then be flooded to completely submerge the unit in clear water so all of its opening and exterior and interior surfaces are thoroughly wetted. | VB-6<br>At a point 1" below the critical level established by the above test the unit shall have stamped in or cast on its sheath distinguishing line and the letters "W.O.L." (water overflow level). This indicates the highest permissible liquid level in any closet tank when used with the unit tested and governs the maximum height of the tank overflow tube, passageway, or conduit. (See Fig. 3, Page 7). | | |
| VC-1<br>VC-2<br>VC-3<br>Test Procedure for Air Gap Type Water Closet Flush Tank Ball Cocks | VC-3<br>At an elevation 1" below the lowest point of the ball cock discharge opening the unit shall have stamped in or cast on the sheath a distinguishing line and the letters "W.O.L." (water overflow level). This indicates the highest permissible liquid level in any closet tank when used with the unit tested and governs the maximum height of the tank overflow tube, passageway, or conduit. (See Fig. 4, Page 9). | VC-1<br>The unit shall be installed in its normal operating position in a test tank having transparent walls and its water supply inlet connected to a vacuum line. The shutoff valve of the unit shall be held in a fully open position and the refill tube positioned outside the overflow tube and its discharge end submerged. The unit shall either be supplied with water or completely submerged in clear water so all openings and interior surfaces are thoroughly wetted. The refill tube shall be fitted with a suitable sight glass. This portion of test not applicable to a ball cock having an air gap discharge and having an integral fixed air gap refill. | VC-2<br>With the water level in the tank 1" below the lowest point of the ball cock discharge opening and with the end of the refill tube submerged,.... | | ....no rise of water shall occur in the refill tube when vacuum is applied as specified in Section V-B5. (See Fig. 4, Page 9). |

Table 15 Matrix Arrangement of Essential Contents of Section 2.0 Performance Criteria and Method of Test Contained in A.S.S.E. Standard No. 1011 "Performance Requirements of Hose-Connection Vacuum Breakers", Dated June 1970.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.1.1 Resistance to Hydrostatic Test | When subjected to two (2) times the rated working pressure the device shall show no external leaks. | Install the device in the test system as in Fig. 1. Admit water through the inlet of the device allowing water to flow through it to purge it of air. | Close the outlet valve and build up the supply pressure to the maximum required test pressure. Allow the device to stand under pressure for five (5) minutes and..... | ....and examine it for leaks. | Any external leaks shall be cause for rejection. |
| 2.1.2 Noise | The device shall not produce any objectionable noises when subjected to any flow rate up to its maximum capacity, at any pressure up to its rated maximum, maintained at the inlet of the device. | | | Conditions of noise shall be observed during tests prescribed in this standard. | Noise other than that due solely to water velocity shall be cause for rejection. |
| 2.1.3 Water Flow Capacity and Pressure Loss | The minimum water flow capacity and maximum pressure loss across the device shall be as in Table I. | Install the device in test system, Fig. 1, which is equipped with means for accurately measuring the rate of water flow and pressure loss across the device. The system shall be connected to a source of water supply adequate to meet the requirements of Table I and maintain the required pressure at the inlet of the device during the test. | Tests shall be run with both 25 psi and 125 psi pressure maintained at the inlet of the device. After purging the system of air, close the outlet, regulate the water pressure at the inlet of the device and maintain it, during the test, at the required level. | Then slowly open the outlet valve until the required rate of flow is obtained or the 25 psi pressure differential is reached. | Failure to obtain the required rate of flow within the 25 psi pressure loss across the device shall be cause for rejection. |
| 2.1.4 Leakage from Vent Ports | When the supply valve is opened to admit water to the device and hose, a leakage from the vent ports, when the pressure in the inlet of the device is below 3 psi, shall not exceed a rate of 1/4 pint per minute. When the inlet pressure is at 3 psi and higher there shall be no leakage from the vent ports. | Install the device on the test system as in Fig. 1. | Close the throttling valve and "crack" open the supply valve very slowly and raise the inlet pressure to the point at which leakage ceases. | During this procedure observe the point at which the highest rate of discharge occurs and adjust the inlet pressure to this point and measure the rate of leakage flow. | A flow rate exceeding 1/4 pint of water per minute shall be cause for the rejection of the device. |
| | | | If the device meets this requirement raise the inlet pressure to 3 psi. | The leakage from the vent ports shall cease. | Continuation of leakage shall be cause for rejection of the device. |
| | | | | | |

Table 15 (Continued) Matrix Arrangement of Essential Contents of Section 2.0 Performance Criteria and Method of Test Contained in A.S.S.E. Standard No. 1011 "Performance Requirements of Hose-Connection Vacuum Breakers", Dated June 1970.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.1.5 Water Hammer Shock Resistance | When subjected to water hammer pressure rise to the quick closing of the spring operated nozzle at the end of the hose, the device shall not be adversely affected. Some spillage during the period of shock wave will not be cause for rejection. Continued leakage after the shock subsides will be cause for rejection. | Install the device as in Fig. 10 with 50 feet of 1/2" inside diameter garden hose connected to its discharge end. A spring-loaded quick-closing nozzle with a 1/4" diameter terminal orifice shall be attached to the discharge end of the hose. | With the nozzle fully open water shall be supplied through the device with 25 psi flowing pressure maintained at the inlet of the device. The nozzle shall be opened and closed at least 4 times. Following each closing of the nozzle the shock wave shall be allowed to dissipate and the ports examined for continuous leakage. The tests shall be repeated with the inlet pressure during the flow maintained at 100 psi. | | Any indication of damage which impairs the intended functions of the device, or continuous leakage from the ports when the shock wave has been disipated, shall be cause for rejection of the device. Transient leakage due to water hammer shock pressure decay following the closing of the nozzle will not be cause for rejection. |
| 2.1.6 Backflow | There shall be no backflow of water through the check valve member into the supply line when the air ports are sealed closed and a back pressure within a range from 6 inches to 10 feet of water column is applied to the outlet of the device. | Install the device as in Fig. 3 with the air ports sealed closed, a transparent tube connected to the inlet of the device and a hose connected to the outlet. | The hose shall be filled with colored water and the outlet end raised to an elevation to produce 6 inch water column at the outlet device. Hold for not less than 5 minutes. Repeat the test with the water column increased by 24 inch increments until a 10 ft. column of water is reached. | Observe the transparent tube for presence of colored water. | Any apperance of colored water shall be cause for rejection. |
| | | | | | |

Table 15 (Continued)Matrix Arrangement of Essential Contents of Section 2.0 Performance Criteria and Method of Test Contained in A.S.S.E. Standard No. 1011 "Performance Requirements of Hose-Connection Vacuum Breakers", Dated June 1970.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.1.7 Back-Siphonage | There shall be no back-siphonage of water from the downstream piping into the supply piping when the check valve seat or disc is fouled in accordance with the test method described below. | The inlet check valve shall be fouled with a wire of .048" diameter. It shall be placed in the appropriate position as shown in Figs. 4, 5, 6 or 7. For any other configuration the wire shall be placed in a position analogous to those shown. See Sub-section 1.6.1.1. The device shall be installed as in Fig. 2, the equipment having the capabilities for producing a vacuum up to 25" mercury column. A transparent sight glass of 1/2" inside diameter shall be connected to the outlet of the device, with its lower end immersed in a reservoir of colored water positioned below the device. | Vacuums up to 25" mercury column shall be gradually applied to the inlet of the device .......<br>The vacuum shall then be applied rapidly alternating between 0" and 25" to create a surge in the line. | .....and the transparent tube observed for any water rise in it. | Any rise in the sight glass shall be cause for rejection.<br>In any test in which there is an upward bowing of the meniscus in the sight glass, the crown of the meniscus shall not exceed the rise of 1/8" above the level level of the water in the reservoir or basin. |
| 2.1.8 Resistance to Bending | Devices for use on hose threaded outlets shall withstand a pull of not less than 100 pounds force on the hose perpendicular to the axes through the hose connections of the device, without permanent distortion or damage to the device which will adversely affect its functioning capabilities. | With the device installed as in Fig. 8........ | ........ by means of its inlet thread apply a load equivalent to a pull of 100 pounds in a direction at right angles to the axis through the hose connections of the device and hold for at least three (3) minutes. During the test the device shall be pressurized to at least 100 psi.<br>Following this test, retest under 2.1.4 and 2.1.6. | | Any visible external leakage during the test shall be cause for rejection of the device. |

Table 15 (Continued) Matrix Arrangement of Essential Contents of Section 2.0 Performance Criteria and Method of Test Contained in A.S.S.E. Standard No. 1011 "Performance Requirements of Hose-Connection Vacuum Breakers", Dated June 1970.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.1.9 Ability to Resist and Relieve Back Pressure | With a connected hose having a spring loaded nozzle attached, the nozzle in a closed position, the device pressurized to its maximum rated working pressure, when the pressure in the inlet is suddenly dropped to zero, the pressure in the hose shall be relieved through the air ports without adversely affecting the device. | Install the device in the test system, Fig. 10, with 50 feet of 1/2 inch garden hose connected to the end of the hose. Open the supply line to the device and admit pressure up to the rated working pressure of the device. | Open the nozzle to purge the line of air and then allow the nozzle to close slowly. Close the supply valve to the inlet of the device and then open a quick-acting bleed to drop the pressure in the inlet of the device to 0 psi. The pressure in the hose line should be dissipated quickly by the discharge of water through the vent ports.<br>Following this test the device shall be retested under 2.1.6. |  | Failure to dissipate the pressure through the vent ports shall be cause for rejection of the device. |
| 2.1.10 Deterioration in Hot and Cold Water | When exposed to hot water, at not less than 190°F. average, for extensive periods, rubber, plastic materials and others, whose memory is essential to the continued functioning of the device, shall not be adversely affected. When exposed to water at between 32 F. and 40 F. the device shall not be adversely affected. | Install the device as in Fig. 9 with a heater capable of maintaining a temperature of 185°F. to 195°F., a reservoir located above the heater and a pump capable of creating a flow of hot water through the device on test of 5 to 7 GPM continuously. The reservoir shall be closed but vented to atmosphere. | Hot water shall be caused to flow through the device for 8 hours per day for a total of 10 days (80 hours). Following this test the device shall be retested for compliance with 2.1.6 and 2.1.7. |  |  |

Table 16 Matrix Arrangement of Essential Contents of Section II, Performance Requirements - Method of Test, Contained in A.S.S.E. Standard No. 1012 "Backflow Preventers with Intermediate Atmospheric Vent", Dated May 1972.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.1 Noise | The device should not produce any objectionable noises when subjected to any flow rate up to its maximum capacity, at any pressure up to its rated maximum maintained at the inlet of the device. | | | Conditions of noise shall be observed during the tests prescribed in the standard and shall be reported. | |
| 2.2 Hydrostatic Test-Total | When subjected to a pressure of two (2) times its rated working pressure the device shall show no external leaks. | Install the device as in Fig. 1. Admit water through the inlet of the device allowing water to flow through it to purge it of air. | Close the discharge valve and build up the supply pressure to the maximum required test pressure. Hold for a period of five minutes.... | .... and examine the device for leaks. | Any external leaks shall be cause for rejection. |
| 2.3 Hydrostatic Test-Check Valve | The outlet (downstream) check valve shall be capable of withstanding, without damage or distortion which will adversely affect the performance of the device, a downstream pressure of not less than two (2) times the rated working pressure of the device when the intermediate chamber is at atmospheric pressure. | With the device installed as in Fig. 1, the intermediate chamber at atmospheric, raise the outlet pressure in the device to two (2) times its rated working pressure | Hold the pressure for at least five (5) minutes. | Observe for external leaks and any other indication of distortion or permanent damage. | |
| 2.4 Tightness of Downstream Check | The downstream check valve shall be drip tight when the intermediate chamber pressure is a minimum of 1 psi and the outlet pressure is at atmospheric. | Equip the device with a transparent tube communicating with the intermediate chamber and secure it in a vertical position. With the device installed as in Fig. 1......<br>The manufacturer shall provide the means for attaching the transparent tube to communicate with the intermediate chamber. | ....and the outlet pressure at atmospheric gradually admit water to the inlet and raise the pressure in the sight glass to 28" water column measured from the center line of the check valve. Close the supply valve and hold for a period of not less than five (5) minutes. | Test apparatus must be observed for leaks which could affect the test and the leaks eliminated before making the final test. | Any lowering water level in the glass shall be cause for rejection. |

Table 16 (Continued) Matrix Arrangement of Essential Contents of Section II, Performance Requirements - Method of Test, Contained in A.S.S.E. Standard No. 1012 "Backflow Preventers with Intermediate Atmospheric Vent", Dated May 1972.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.5 Tightness of Inlet Check | The inlet (upstream) check valve shall hold drip tight when subjected to a pressure of not less than 1 psi (28" water column) applied to the inlet with intermediate chamber pressure at atmospheric. | Install the device as in Fig. 5. Block open the downstream check valve by suitable means or remove it. Open the needle valve wide. | Crack the supply valve to raise the water level in the sight glass to 28" above the centerline of the inlet check valve, then close the valve. Hold for five(5) minutes..... | .....observing the water level in the sight glass. | Loss of level in the glass or discharge of water from the outlet of the device shall be cause for its rejection. |
| 2.6 Atmospheric Vent Valve Leakage | There shall be no leakage from the vent port when the supply valve in the pipe line is opened to admit water to the system through the device regardless of the rate at which the supply valve is opened, nor shall there be any leakage at any flow rate up to the capacity rating of the device. | The device shall be installed as in Fig. 1 with means for accurately measuring the rate of flow through the device. A pressure of approximately 10 psi shall be maintained upstream of the supply valve. | With the discharge valve opened slightly, open the supply valve very slowly until the pressure in the inlet of the device is at full supply pressure. Repeat the test with the supply pressure at approximately the rated working pressure of the device. If no leakage is observed, close the discharge valve, open the supply valve fully and then gradually open the discharge valve until the flow through the device is at approximately full capacity. | | Leakage from the vent port(s) during any of these tests shall be cause for rejection |
| 2.7 Backflow Through Inlet Check | There shall be no backflow of water into the inlet of the device when the vent outlet is sealed closed, the outlet check is held partially open and with respective pressures of 6" water column, 15 psi and the maximum rated working pressure of the device are applied in succession to the outlet of the device. | By suitable means hold the outlet check valve in a partially open position and seal the vent outlet closed. Install the device as in Fig. 5 with reservoir filled with colored water. | Gradually raise the pressure in the outlet until pressure equals 6" water column. Hold for five (5) minutes<br>Repeat with a pressure of 15 psi and then with a pressure equal to the rated working pressure of the device. | Observe for the appearance of colored water in the inlet of the device | Any leakage through the valve into the inlet shall be cause for rejection. |

Table 16 (Continued) Matrix Arrangement of Essential Contents of Section II, Performance Requirements - Method of Test, Contained in A.S.S.E. Standard No. 1012 "Backflow Preventers with Intermediate Atmospheric Vent", Dated May 1972.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.8 Atmospheric Vent-Opening Pressures | Under a backflow pressure condition the atmospheric vent shall be open when the supply pressure is 20% less than the downstream pressure. | Install the device as in Fig. 1 Remove the downstream check valve or hold open by suitable means. Purge the system of air and pressurize the system to approximately 25 psi. | Slowly bleed down the supply pressure until water discharge from the atmosphere vent is observed ......<br>Repeat the test at 75 psi and 150 psi. | ...... and record the pressure difference between supply and downstream pressure. | |
| 2.9 Back-Siphonage | There shall be no back-siphonage of water from the downstream piping into the supply line should both check valve seats become scored or fouled with debris and a vacuum is created in the inlet of the device and the downstream pressure is atmospheric. | The inlet check valve shall be fouled with an appropriate size fouling wire as shown in Table 3 in the location shown for the type of valve construction (See Figs. 2, 3, and 4) and the outlet check valve is held open by mechanical means. The device shall be installed as in Fig. 6. Test equipment shall be capable of developing a vacuum of at least 25" mercury column. | Tests shall be conducted in sequence as follows: (a) Apply and hold a vacuum of 25" for not less than one minute. (b) Raise vacuum slowly from 0" to 25" and then slowly reduce it from 25" to 0". (c) By means of a quick acting valve create a surge effect by quickly opening and closing the valve. During this test the vacuum must be ranging between 25" and 0". | In any test in which there is an upward bowing of the meniscus of the water in the sight glass, the crown of the meniscus shall not exceed a rise of 1/8" above the level of the water in the reservoir or basin. | Any rise in the sight glass shall be cause for rejection. In |
| 2.10 Flow and Pressure Loss | The minimum water flow capacity and the maximum allowable pressure loss across the device shall be as shown in Table 4. | The test system, Fig.1, shall be equipped with means for accurately measuring the rate of flow through the device and indicating or recording pressures. Pressure gauges shall be located approximately 5 pipe diameters upstream and 10 downstream of the device. The supply system shall be capable of supplying a volume of cold water adequate to meet the maximum flow requirements of the device on test while sustaining a steady inlet pressure of not less than 25% of the rated working pressure of the device. Purge the air from the system and then close the discharge valve. | Open the supply valve fully and gradually open the discharge valve until the minimum required rate of flow is reached or the maximum allowable pressure loss is obtained.. | ....and record the data observed. Adjust for pressure loss in the piping between the gauges and the device on test. | Failure to achieve the minimum required flow rate at or below the maximum allowable pressure loss shall be cause for rejection of the device. |

Table 16 (Continued) Matrix Arrangement of Essential Contents of Section II, Performance Requirements - Method of Test, Contained in A.S.S.E. Standard No. 1012 "Backflow Preventers with Intermediate Atmospheric Vent", Dated May 1972.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.11 Flow with Low Supply Pressure | With a supply pressure of 10 psi the device shall be capable of a flow of not less than 20% of its rated flow capacity. | Install the device as in 2.9. Purge the system of air. | Open the discharge valve fully, then slowly open the supply valve, gradually increasing the supply pressure....... | ....while observing the indicated rate of flow equals 20% of the rated flow of the device. Adjustment shall be made for the pressure loss in the piping between the gauges and the device on test. | Failure to meet this requirement shall be cause for rejecting the device |

Table 17 Matrix Arrangement of Essential Content of Section 2.0, Performance Requirements - Methods of Test, Contained in A.S.S.E. Standard No. 1013 "Performance Requirements for Reduced-Pressure Principle Back Pressure Backflow Preventers," Dated June 1971.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.1 Hydrostatic Test -Full | The device shall be subjected to a hydrostatic pressure of two (2) times the rated working pressure applied at the inlet. | Install as in Fig. 1. | Purge the system of air and pressurize to test pressure. Hold for five minutes. | Observe for external leaks or other indications of damage. | Any leaks or indication of damage shall be cause for rejection of the device. |
| 2.2 Hydrostatic Test -Outlet Only | A pressure of two (2) times the rated working pressure applied to the outlet of the device with inlet and intermediate chamber pressure at atmospheric shall cause no leakage, or damage to the check valve which will adversely affect its capability for complying with the other requirements of this standard. | Following the test of paragraph 2.1....... | drop the supply pressure to atmospheric while holding the outlet pressure at two (2) times the rated working pressure for ten (10) minutes. |  | Any observed conditions of damage or continuous discharge from the relief valve shall be cause for rejection. |
| 2.3 Outlet Check Valve -Drip Tightness | The outlet check valve shall be drip tight when the intermediate pressure is 1 psi and the outlet pressure is atmospheric. | With the device installed as in Fig. 1, attach a transparent tube, not less than 48 inches long, to the intermediate chamber test cock tapping as shown in Fig. 2. Fill the system and purge it of air. Valves 3 and 4 must remain open. | Admit water slowly through the inlet until the water level in the tube is at least 42" measured from the center of the pipe line or the center of the disc face, whichever is appropriate. Close the supply valve tightly and hold in a closed position for five (5) minutes. | During the test all external connections shall be observed for the detection of leaks which would affect accurate test results and the leaks eliminated. | Any loss of level in the sight glass below 28" shall be cause for rejection of the device. |
| 2.4 Rated Flow -Allowable Pressure Loss | The required rated water flow and maximum allowable pressure loss shall be as shown in Table 2. | Install the device as in Fig. 1 with gauge cocks 7, 8 and 9 closed and a manometer or differential pressure gauge connected to positions 10 and 11. These connections shall be to ring piezometers. The water supply source shall be capable of supplying a volume of water adequate to meet the flow requirements of the size of device on test and maintain an inlet pressure of at least 10 psi greater than the allowable pressure loss at rated flow. | Purge the system of air, then gradually increase the flow of water through the device until the required rated flow of water is achieved or the maximum allowable pressure loss is reached. | The pressure loss through valves and piping between the device on test gauges 10 and 11 must be substracted from the differential pressure reading between the gauges 10 and 11. | Failure to obtain the rated flow at or below the maximum allowable pressure loss shall be cause for rejection of the device. |

Table 17 (Continued) Matrix Arrangement of Essential Content of Section 2.0, Performance Requirements - Methods of Test, Contained in A.S.S.E. Standard No. 1013 "Performance Requirements for Reduced-Pressure Principle Back Pressure Backflow Preventers", Dated June 1971.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.5<br>Zone Pressure vs. Inlet Pressure<br>-<br>Flowing Status | When operating under either static or flow conditions, the intermediate zone pressure shall be at least 2 psi lower than the pressure in the inlet of the device. | Install the device as in test system Fig 1. | During forward flow of water through the device....... | ....the difference between the inlet pressure and the intermediate chamber pressure shall be observed and recorded. | A pressure difference of less than 2 psi during either flowing or static conditions shall be cause for rejection of the device. |
|  |  |  | For the static test close downstream valve 3, upstream valve 1, ....... | ...and observe the pressure difference between the inlet and intermediate chamber pressure. |  |
|  |  |  | Hold in static condition for five (5) minutes. Any reduction of differential pressure would indicate an internal leak between the inlet and intermediate chamber. |  |  |
| 2.6<br>Zone Pressure vs. Inlet Pressure<br>Static Status | Where there is a static operating condition and the supply pressure falls off to 2 psi, the pressure in the intermediate chamber, or zone, shall brcome atmospheric. | With the device installed as in Fig. 1., install a suitable pressure gauge at No.8 in combination with the intermediate chamber connections to the differential gauge. Open the supply valve to purge the system of air, close test cock No. 9 and valve No. 3, raise pressure in the inlet of the device to approximately 25 psi and close valve No. 1. | Slowly bleed down the inlet pressure to open the relief means to allow water to discharge from the intermediate chamber to atmospheric. Continue to bleed down the inlet pressure until the pressure in the chamber is at atmospheric and immediately close the bleed valve. |  | A pressure of less than 2 psi indicated by the differential gauge shall be cause for rejection of the device. |

Table 17 (Continued) Matrix Arrangement of Essential Content of Section 2.0, Performance Requirements - Methods of Test, Contained in A.S.S.E. Standard No. 1013 "Performance Requirements for Reduced-Pressure Principle Back Pressure Backflow Preventers", Dated June 1971.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.7(a) Relief Discharge Rate<br>Backflow Condition | Where there is a backflow and the supply pressure is 2 psi or greater, the relief valve shall discharge water from the zone to atmosphere at the rate of discharge corresponding to the data shown in Table 3, and the pressure in the zone shall be at least 0.5 psi below supply pressure. | Install the device as in Fig.1 with test harness. By mechanical means hold the outlet valve wide open. Install a gauge in the test cock 10 and open test cock 7 and 8. Purge the system of air and pressurize it to approximately 25 inlet pressure. Close supply valve 1 and downstream valve 4. | Open supply valve 5 in the secondary water supply, then slowly open valve 6 until the specified rate of discharge from the relief valve is reached as shown in Fig. 3. | Observe and record the supply pressure and the differential pressure. | A pressure differential between the inlet and intermediate chamber of less than 1/2 psi, as measured by the differential gauge, shall be cause for rejection of the device. |
| 2.7(b) Relief Discharge Rate -Backflow Condition | When there is backflow and the supply pressure is less than 2 psi, the relief valve shall discharge water from the zone to atmosphere with the rate of discharge corresponding to the data shown in Table 3 and the pressure in the zone shall not exceed 1.5 psi. | Close the secondary supply valve 5. Disconnect the test harness from test cocks 7 and 8. Install a sight glass on test cock No. 8 as shown in Fig. 2. | Allow inlet pressure to fall to atmosphere via test cock 7. Open supply valve 5 in the secondary water supply until the specified rate of discharge from the relief valve is reached as shown in Table 3. | Observe and record the pressure shown on the sight glass. | A pressure greater than 42 inches of water shall be cause for rejection of the device. |

Table 17 (Continued) Matrix Arrangement of Essential Content of Section 2.0, Performance Requirements - Methods of Test, Contained in A.S.S.E. Standard No. 1013 "Performance Requirements for Reduced-Pressure Principle Back Pressure Backflow Preventers", Dated June 1971.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.8 Relief Valve Opening and Closing | The pressure relief or atmospheric vent valve shall start to open when the pressure in the intermediate chamber is at least 2 psi lower than the pressure in the inlet of the device. It shall open and close positively. | Install the device as in Fig. 1 including a by-pass with a needle valve, between test cocks 7 and 8. Purge the system of air and pressurize the system to approximately 25 psi. | (a) open slightly the needle valve in the by-pass until the gauge shows a decreasing differential pressure.<br>(b) Close the needle valve and open the supply valve to restore the inlet pressure. The relief valve must reclose tightly. | | (a) A reading of less than 2 psi at the time of opening of the relief valve shall be cause for rejection of the device.<br>(b) Failure to close drip tight shall be cause for rejection of the device. |
| 2.9 Relief Valve Discharge vs. Inlet Pressure Surge | The relief valve shall not discharge water under supply pressure fluctuations of 1-1/2 psi maximum variation. | Install the device as in Fig. 1. Purge the system of air and pressurize to approximately 25 psi static pressure in the inlet of the device. | Within a 10 second period change the inlet pressure to 1-1/2 psi, then to -1-1/2 psi and back to the static pressure level. | | Any discharge from the relief valves during these tests shall be cause for rejection of the device. |

Table 18 Matrix Arrangement of Essential Contents of Section 2.0, Performance Requirements - Methods of Test, Contained in A.S.S.E. Standard No. 1015 "Performance Requirements for Double Check Valve Type Back Pressure Backflow Preventers", Dated May 1972.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.1 Hydrostatic Test Full | The device shall be subjected to a hydrostatic pressure of two (2) times the rated working pressure applied at the inlet. | Install as in Fig. 1. | Purge the system of air and pressurized to test pressure. Hold for five (5) minutes. | Observe for external leaks or other indications of damage. | Any leaks or indications of damage shall be cause for the rejection of the device. |
| 2.2 Hydrostatic Back Pressure Test of Check Valves | A pressure of two (2) times the rated working pressure applied to the downstream side of each check valve individually with pressure on the upstream side at atmospheric shall cause no damage nor leaks by the check valves. | Install the device as in Fig. 1 with a sight glass (Fig. 2), shut-off and drain cock installed in the test cock tapping No. 1 upstream of the inlet check valve. By suitable means hold the downstream check valve partially open. | Purge the device of air, close the supply valve, open the shut-off cock to the sight glass. Adjust the water level in the sight glass to be at the height not less than that corresponding to the top of the water space in the device. Raise the pressure downstream of the check valve to two (2) times the rated working pressure of the device and record the water level in the sight glass. Hold for not less than five (5) minutes. | Observe for indications of damage or leaks by the check valve. | |
| | | Repeat the test with upstream check valve held partially open, the sight glass installed in the test cock tapping between the check valves, the downstream check in a fully closed position....... | And pressure of two (2) times the rated working pressure applied on the downstream side of the check valve with atmospheric pressure on the upstream side. Hold for not less than five (5) minutes....... | And observe for indication of damage or leaking by the check valve. Any rise in the sight glass is an indication of leaking by the check valve. | |

Table 18 (Continued) Matrix Arrangement of Essential Contents of Section 2.0, Performance Requirements - Methods of Test, Contained in A.S.S.E. Standard No. 1015 "Performance Requirements for Double Check Valve Type Back Pressure Backflow Preventers", Dated May 1972.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.3 Tightness of Check Valves Against Upstream Pressure of 1 psi | Each check valve shall be drip tight when a pressure of not less than 1 psi is applied to the upstream side with atmospheric pressure on the downstream side. | Install the device as in Fig. 1 with a sight glass (Fig. 2), shut-off and drain cock assembly installed in the test cock tapping No. 1 upstream of the inlet check valve. By suitable means hold the downstream check valve partially open. Purge the device of air and open the shut-off cock to the sight glass. | With the downstream gate and throttling valve open, pressurize the inlet of the device to a water column of at least 42" measured from the center of the pipe line or the center of the disc face. Close the filling or supply valve tightly. Hold for not less than five (5) minutes. | | Any loss of level in the sight glass below 28" shall be cause for rejection. |
| | | Allow the downstream check to close and apply the same test to it. With the sight glass installed in the test cock tapping 2 between the check valves and.... | ....with atmospheric pressure downstream of the check valve, pressurize the upstream side to not less than 42" in the sight glass measured from the center of the pipe line or the center of the disc face. Hold for not less than five (5) minutes. | | Any reduction in the height of the water level below 28" in the sight shall be cause for rejection. |
| 2.4 Rated Flow and Pressure Loss | The minimum rated water flow and maximum pressure loss shall be as shown in Table 2. | Install as in Fig. 1 with a differential manometer of pressure indicating instrument connected to positions where the gauges are shown. These connections shall be to ring piezometers. The supply source shall be capable of supplying a volume of water adequate to meet the flow requirements of the size of device on test maintain an inlet pressure of at least 10 psi greater than the allowable pressure loss at rated flow. | Purge the system of air, then gradually increase the flow of water through the device until the required rated flow of water is achieved or the maximum allowable pressure loss is reached. | The pressure loss through valves and piping between the device on test and piezometer connections must be subtracted from the differential pressure reading between piezometer connections. | Failure to obtain the rated flow at or below the maximum allowable pressure loss shall be cause for rejection of the device. |

Table 19 Matrix Arrangement of Essential Contents of Section 2.0, Performance - Method of Test, Contained in A.S.S.E. Standard No. 1020 "Performance Standard for Vacuum Breakers, Anti-Siphon, Pressure Type", Dated November, 1974.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.1 Hydrostatic Test | 2.1.1 The device shall be subjected to a hydrostatic pressure of two (2) times the rated working pressure applied at the inlet of the device | Connect the device to a suitable water supply source capable of supplying the required pressure. Water shall be caused to flow through the device to purge it of air and the downstream shut-off valve then closed. Any air vent cocks which are provided must be opened during this purging cycle to vent trapped air. | Raise the pressure slowly to the required test pressure...<br>Hold under pressure for not less than five (5) minutes. | ...and observe for leaks and any other indications of damage. | Any damage shall be cause for rejection. |
| | 2.1.2 The check valve(s) shall be capable of withstanding, without damage, a back pressure of two (2) times the rated working pressure with atmospheric pressure on the upstream side. | (a) Devices with a single check valve. Install as in Fig. 1 or 1A. Connect the inlet to a water supply and the #2 test cock to a source which will produce an adequate hydrostatic pressure. Purge the system of air. Install a sight glass, with a drain cock on test cock #1. | Close the #2 shut-off valve and then close the #1 shut-off valve. Open the drain cock under the sight glass and lower the water level in the sight glass to a height corresponding to the top of the device on test. Slowly raise the pressure on the downstream side of the check valve to the required test pressure... | ...observing for indications of leakage or damage to the check valve. | |
| | | | ...Hold for five (5) minutes... | ...The water level in the sight glass should reach and hold a steady level. | |
| | | (b) Devices with two (2) check valves. Install as in Fig. 2. For testing the #1 check valve, install the sight glass in #1 test cock and the hydrostatic pressure line to #2 test cock.. | ...and then proceed as for (a). | | |
| | | For testing the #2 check valve install the sight glass in #2 test cock and the hydrostatic pressure line to #3 test cock... | ..and then proceed as in (a). | | ailure to meet he requirements f this sub-ection shall e a cause for ejection of he device. |

Table 19 (Continued) Matrix Arrangement of Essential Contents of Section 2.0, Performance - Method of Test, Contained in A.S.S.E. Standard No. 1020 "Performance Standard for Vacuum Breakers, Anti-Siphon, Pressure Type", Dated November, 1974.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.2 Check Valves - Force Loading or Biasing | The check valves shall hold pressure tight against a pressure of not less than 1 psi applied in the direction of normal water flow with a pressure downstream at atmospheric. | (a) Devices having one check valve. With the device setup as in Fig. 1 or 1A, install the sight glass in #1 test cock.<br>The downstream face of the check valve must be free of water and at atmospheric pressure. | Raise the water level to a height in excess of 27-3/4 inches measured from the seat face of the check valve, if in a horizontal plane, or the center of the disc if in other than a horizontal plane.<br>Hold until the water level in the sight glass reaches and holds steady level. | | |
| | | (b) Devices having two (2) check valves. Install as in Fig. 2. For the #1 check valve, install the sight glass in the #1 test cock..... | .....and proceed as in (a) | Loss of water level below 27-3/4 inches ....... | ....shall be cause for rejection |
| | | For the #2 check valve install the sight glass in the #2 test cock..... | .....and proceed as in (a) | | |
| 2.3 Atmospheric Vent Valve Opening Pressure. | The atmospheric vent valve shall start to open when the line pressure falls to not less than 1 psi and be fully open when the line pressure is at atmospheric. | With the device installed as in Fig. 1 or Fig. 2, install a sight glass in the downstream test cock. Remove the air vent protective canopy or other shielding means so as to expose the valve for observation. Open the test cock in which the sight glass is installed and pressurize the system to 30" or more water column measured from the vent seat to the water level in the sight glass. Clear any accumulated water from around the well above the vent valve. | Slowly drain water from the system until the vent valve starts to open. | Record the water level in the sight glass. It should not be less than 27-3/4 inches. | |
| | | | Continue to drain water from the test system until the pressure at the vent valve is atmospheric. | The vent valve must be fully open. | Failure to meet these requirements shall be cause for rejection of the device. |

Table 19 (Continued) Matrix Arrangement of Essential Contents of Section 2.0, Performance - Method of Test, Contained in A.S.S.E. Standard No. 1020 "Performance Standard for Vacuum Breakers, Anti-Siphon, Pressure Type", Dated November, 1974.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.4 Air Passage Comparative Areas | The device shall be subjected to tests to compare the effective throughway area from its water inlet to outlet in relation to its available internal air relief area. | Tests shall be conducted as follows: (1) Install the device in the normal operating position with the check or moving member held fully open and the air valve held closed. Connect the discharge outlet of the device by means of 12" length of reamed corresponding size piping to an adequately sized vacuum tank capable of providing at least a 10 second air flow, and with the inlet open and a 12" reamed nipple of corresponding size threaded into the inlet. | Dissipate the vacuum in the tank 25" to 5" of mercury through the check valve orifice by operating a quick opening valve...... | .....timing the operation | |
| | | (2) With the discharge outlet still connected to the vacuum tank and the inlet check held in a closed position.............. | ......hold the air valve open and dissipate the vacuum in the tank from 25" to 5" of mercury in the same matter through the air port or ports............. | .....timing the operation.<br>(3) The time for (2) shall be equal to or less than (1) based on the average result of not less than three test runs, indicating that the opening(s) to atmospheric is (are) equal to or greater than the effective waterway through the device. | |

Table 19 (Continued) Matrix Arrangement of Essential Contents of Section 2.0, Performance - Method of Test, Contained in A.S.S.E. Standard No. 1020 "Performance Standard for Vacuum Breakers, Anti-Siphon, Pressure Type", Dated November, 1974.

| Paragraph Number and Title | Test Requirements | Test Setup and Preparation for Testing | Test Procedure | Observations Records and Computations | Basis for Rejection of Device |
|---|---|---|---|---|---|
| 2.5<br>Back-siphonage Prevention | There shall be no back-siphonage of liquid through the device when the check valve seat(s) is (are) fouled with a wire of the diameter shown in Table 3, corresponding to the size of device on test when variable vacuums from "0" to 25" mercury column are applied to the inlet. | The fouling wire shall be furnished by the manufacturer, formed to fit the contour of the check valve(s) seat and be of a size shown in Table 3. Means for holding the wires securely in the position as basically illustrated by Figures 3, 4, 5 and 6 shall be provided by the manufacturer.<br>A water manometer shall be installed in the test cock #2 for devices with single check valves and in test cock #3 for valves with more than one check valve. The device shall be connected to a source of vacuum which shall be capable of producing and sustaining a 25" mercury column for periods adequate for the tests. | The following tests shall be run on each valve submitted for test. Each test shall be repeated to obtain five (5) sets of comparative data.<br>(a) Apply a constant vacuum of at least 25" of mercury for a period of at least 30 seconds.<br>(b) Apply intermittent vacuums of 2, 5, 10, 15, and 25 inches of mercury. Each application shall be for 5 seconds on and 5 seconds off.<br>(c) First, slowly apply a vacuum increasing at a uniform rate from 0" to 25" of mercury. Second, slowly apply a vacuum decreasing at a uniform rate from 25" to 0" of mercury. | A manometer reading of more than 6"... | ...shall be cause for rejection of the device. |
| 2.6<br>Rated Flow and Maximum Allowable pressure loss. | The rated flow and maximum allowable pressure loss at rated flow shall be as in Table 2. | The test system shall be equipped with means for accurately measuring the rate of flow through the device and indicating or recording pressure loss. Pressure gauges shall be located approximately five (5) pipe diameters upstream of the inlet of the device and ten (10) pipe diameters downstream of the device. The supply system shall be capable of supplying a volume of cold water adequate to meet the maximum flow requirements of the device on test while sustaining a steady inlet pressure of not less than 25% of the rated pressure of the device. Purge the air from the system... | and then close the discharge valve until the minimum required rate of flow is reached or the maximum allowable pressure loss is obtained... | ...and record the data observed. Adjust for pressure loss in piping between the gauges and the device on test. | Failure to achieve the minimum required flow rate at or below the maximum allowable pressure loss shall be cause for rejection of the device. |

## Table 20 Descriptive Cataloging of Five Backflow Prevention Devices Indexed to Comparable Paragraphs of the Respective A.S.S.E. Standards

| Pipe Applied Atmospheric Type Vacuum Breakers | Hose Connection Vacuum Breakers | Backflow Preventers With Intermediate Atmospheric Vent | Reduced Pressure Principle Back Pressure Backflow Preventers | Double Check Valve Type Back Pressure Backflow Preventers |
|---|---|---|---|---|
| A.S.S.E. No. 1001<br>October, 1970 | A.S.S.E. No. 1011<br>June, 1970 | A.S.S.E. No. 1012<br>May, 1972 | A.S.S.E. No. 1013<br>June, 1971 | A.S.S.E. No. 1015<br>May, 1972 |
| 2.6<br>Classed in this group of devices are only those that perform the single function of back-siphonage prevention;not included are the atmospheric types used in conjunction with other controls(such as an anti-siphon ballcock) or vacuum relief valves.<br>4.4<br>The basic function of the device is accomplished by means of a check valve and an air relief valve.<br>2.3<br>It is designed to operate only on the discharge side of a control valve.<br>3.7.5<br>It must not leak or spill water even under conditions of minimum flow and/or flow pressure.<br>1.2<br>It must be installed with the C-I-L point at least 6" above the flood level rim of the receptacle served. | 1.1.1<br>The design embraces a check valve member force-loaded,or biased, to a closed position and an atmospheric vent valve, or means, force-loaded to an open position when the device is not under pressure.<br>1.1.2<br>The device is intended for the protection of the potable water supply against contaminants which could otherwise enter the water system by back-siphonage or back-pressure backflow through the hose-threaded outlets.<br>1.1.1<br>It is designed to be installed on the discharge side of the control valve.<br>Foreword<br>To be effective it must be so installed that the air ports cannot be submerged. | 1.1.1.1<br>Such devices have two independently operating check valves separated by an intermediate chamber with a means for automatically venting it to the atmosphere. The check valves are force loaded to a normally-closed position and the venting means is force loaded to a normally-open position.<br>1.1.2<br>Should not be used for building isolation, but may be used back-pressure backflow and/or back-siphonage involves contaminants of low hazard.<br>1.1.1.1<br>The device can operate under continuous or intermittent pressure conditions.<br>1.7.1<br>It must not be installed in a concealed or inaccessible location or where venting of water would be objectionable. | 1.1.1.1<br>The device consists of two independently acting check valves internally force-loaded to a normally closed position and separated by an intermediate chamber or zone in which there is an automatic relief means for venting to atmosphere. Such means is internally force-loaded to a normally-open position.<br>Foreword and 1.1.1.1<br>It is designed primarily for the prevention of backflow due to back pressure and to operate under continuous pressure conditions.<br>Foreword of A.S.S.E. 1012<br>The device is considered to be the best available for building isolation or for high health hazard conditions<br>1.3.7<br>The design must incorporate provision for bleeding trapped air from the device. | 1.1.1.1<br>The device consists of two independently operating check valves, internally loaded to a normally-closed position.<br>1.1.1.1<br>It may be used under intermittent or continuous pressure conditions.<br>1.1.2<br>This type of device is considered suitable for use only where there is no health hazard. |
| 4.5 and Fig. 2<br>Sizes are 1/8",1/4",1/2",3/4",1",1-1/4",1-1/2",2",2-1/2",3" and 4". | 1.2.2<br>The two sizes here 3/4" and 1" hose connection threads. | 1.1.1.2<br>Inlet and outlet pipe sizes are 1/4", [illegible]8", 1/2",and 3/4". | 1.1.1.2<br>Connection pipe sizes are: 1/2", 3/4", 1", 1-1/4", 1-1/2",2",2-1/2", 3", 4", 6",8",10",12",14",and 16". | 1.1.1.2<br>The sizes shall be 1/2", 3/4",1",1-1/4",1-1/2", 2", 2-1/2", 3", 4", 6", 8", 10", 12", 14", and 16". |
| 3.2.1 and 3.2.2<br>Devices for cold water supply lines only have a working temperature range from 32°F to 110°F. For use with either hot or cold water the temperature range is from 32°F to 212 °F. | 1.2.1 and 2.1.10<br>It must be suitable for both hot and cold water service.The working temperature range is 32°F to 190°F. | 1.1.1.4<br>The temperature range is 40°F to 220°F. | 1.1.1.4<br>For cold water service the temperature range is 33°F to 110°F and for hot water service the range is above 110°F. | 1.1.1.4<br>For cold water service the temperature range is 33°F to 110°F and for hot water service the range is above 110°F. |
| 3.2 and 4.2<br>The hydrostatic working pressure is 125 psi. | 1.2.3<br>The minimum working pressure is 125 psi. | 1.1.1.3<br>The working pressure must be not less than 150 psi. | 1.1.1.3<br>The working pressure must be at least 150 psi. | 1.1.1.3<br>The working pressure must be at least 150 psi. |
| 3.1<br>The entire assembly shall be certified by the manufacturer to be of nontoxic materials, when used with potable water. | 1.3.1<br>All material in contact with the water flowing through the device which can,in any way, contaminate the water so that it may be injurious to persons consuming it, are prohibited..... | 1.4.6<br>All material in contact with the water flowing through the device which can,in any way, contaminate the water so that it may be injurious to persons or animals consuming it,are prohibited..... | 1.4.7<br>All material in contact with the water flowing through the device which can, in any way, contaminate the water so that it may be injurious to persons consuming it, are prohibited....... | 1.4.8<br>All material in contact with the water flowing through the device which can, in any way, contaminate the water so that it may be injurious to persons consuming it, are prohibited...... |
| 3.2.1. and 4.2<br>Must withstand 3 ten-minute hydrostatic tests at 32°F and also 3 ten-minute tests at 110°F for cold water service at 125 psi. | 2.1.1<br>Must withstand for a 5-minute period a hydrostatic test of 2 times the rated working pressure. | 2.2<br>Must withstand for a 5 minute period a hydrostatic test of two times rated working pressure. | 2.1<br>It must withstand for 5 minutes a hydrostatic test at two times the rated working pressure applied at the inlet. | 2.1<br>It must withstand a 5-minute hydrostatic test at two times the rated working pressure which is 150 psi minimum. |

## Table 20 Descriptive Cataloging of Five Backflow Prevention Devices Indexed to Comparable Patagraphs of the Respective A.S.S.E, Standards

| Pipe Applied Atmospheric Type Vacuum Breakers | Hose Connection Vacuum Breakers | Backflow Preventers With Intermediate Atmospheric Vent | Reduced Pressure Principle Back Pressure Backflow Preventers | Double Check Valve Type Back Pressure Backflow Preventers |
|---|---|---|---|---|
| A.S.S.E. No. 1001<br>October, 1970 | A.S.S.E. No. 1011<br>June, 1970 | A.S.S.E. No. 1012<br>May, 1972 | A.S.S.E. No. 1013<br>June, 1971 | A.S.S.E. No. 1015<br>May, 1972 |
| 3.2.2.. and 4.2<br>Must withstand 3 ten-minute hydrostatic tests at 32°F and also 3 ten-minute tests at 212°F for hot water service at 125 psi. | | 2.3<br>The outlet check valve must withstand for a 5-minute period, two times the rated working pressure on the downstream side with atmospheric on upstream side. | 2.2<br>The outlet check valve must withstand for 10 minutes, two times the rated working pressure on the downstream side with atmospheric pressure in the inlet and intermediate chambers. | 2.2<br>Each check valve must withstand two times the rated working pressure on downstream side and atmospheric on upstream side for a 5-minute period. |
| | | 2.4 and 2.5<br>Each check valve must be drip tight when not less than 1 psi is applied to upstream side and atmospheric pressure to downstream side. | 2.3<br>The outlet check valve must be drip tight when the intermediate pressure is 1 psi and the outlet pressure is atmospheric. | 2.3<br>Each check valve must be drip tight when not less than 1 psi is applied to upstream side and atmospheric to downstream side. |
| | 2.1.3<br>At the minimum flows (gpm) given in table 1, the pressure loss must not exceed 25 psi. | 2.10<br>At rated flow (gpm from table 4) the pressure loss shall not exceed 25 psi. | 2.4<br>At rated flow (gpm and psi from table 2) the pressure loss must not exceed the maximum allowable. | 2.4<br>At rated flow (gpm from table 2) the pressure loss must not exceed 10 psi. |
| | | | 2.5<br>Under either static or flow conditions the intermediate zone pressure must be at least 2 psi lower than the inlet. | |
| | | | 2.6<br>During static operating condition, should supply pressure fall to 2 psi then pressure in the zone must become atmospheric. | |
| | | | 2.7a<br>During backflow condition with supply pressure 2 psi or more, the zone must discharge to atmosphere at rate shown in table 3 and zone pressure must be at least 0.5 psi below the supply pressure. | |
| | | | 2.7b<br>During backflow condition with supply pressure less than 2 psi, the zone must discharge to atmosphere at rate shown in table 3 and the zone pressure must not exceed 1.5 psi. | |
| | 2.1.4<br>At 3 psi inlet pressure ther must be no leakage from vent port. Below 3 psi, leakage must not exceed 1/4 pint per minute. | | 2.8<br>The atmospheric vent valve must start to open when pressure in zone is at least 2 psi lower than pressure in inlet. It must open and close positively. | |
| | 2.1.9<br>With the device connected as in Fig. 10 to 50 ft. of 1/2" hose at rated pressure, if the pressure at the inlet drops suddenly to 0 psi, the pressure in the hose must dissipate quickly through the vent ports. | 2.6<br>There must be no leakage from the vent port when the supply valve is opened regardless of the rate at which it is opened, nor any leakage at any flow rate up to the capacity rating of the device. | 2.9<br>The relief valve must not discharge water under supply pressure fluctuations of 1-1/2 psi maximum variation. | |

Table 20 Descriptive Cataloging of Five Backflow Prevention Devices Indexed to Comparable Paragraphs of the Respective A.S.S.E. Standards

| Pipe Applied Atmospheric Type Vacuum Breakers | Hose Connection Vacuum Breakers | Backflow Preventers With Intermediate Atmospheric Vent | Reduced Pressure Principle Back Pressure Backflow Preventers | Double Check Valve Type Back Pressure Backflow Preventers |
|---|---|---|---|---|
| A.S.S.E. No. 1001<br>October, 1970 | A.S.S.E. No. 1011<br>June, 1970 | A.S.S.E. No. 1012<br>May, 1972 | A.S.S.E. No. 1013<br>June, 1971 | A.S.S.E. No. 1015<br>May, 1972 |
|  | 2.1.6<br>With the air ports sealed, the device must prevent backflow during 5-minute tests at 0.22,1.08, 1.95, 2.82, 3.08, and 4.33 psi back pressure on the inlet check valve. | 2.7<br>With the vent outlet sealed closed and the outlet check held partially open, the must be no leakage through the inlet check as pressures of 0.2, 15 and rated psi are applied successively for 5 minutes each at the outlet of the device.<br>2.8<br>The atmospheric vent must be open when the supply pressure is 20% less than downstream. |  |  |
| 3.5 and 4.5<br>With the check valve seat fouled with a test wire, the inlet connected to a vacuum line, and the outlet connected by a sight tube extending downward 6 inches into a water surface, as varying vacuums are applied to the inlet water rise in the sight tube must not exceed 3". | 2.1.7<br>With the inlet check valve fouled by a test wire, the device must withstand back-siphonage vacuums of 25 inches of mercury column applied to the inlet either gradually or rapidly alternating from 0" to 25" to 0" etc. | 2.9<br>With a vacuum at the inlet and atmospheric pressure at the outlet, and both check valve seats fouled, there must be no back-siphonage to the inlet.<br>2.11<br>With a supply pressure of 10 psi the flow rate must be not less than 20% of rated capacity. |  |  |
|  | 2.1.10<br>When tested ( see fig 9) with hot water flowing at 5 to 7 gpm for 10 days of 8 hours each at temperatures of 190°F 5°F, the nonmetallic materials in the device must not be adversely affected. |  |  |  |
|  | 2.1.5<br>Must withstand a water hammer test of four shocks each at 25 psi and at 100 psi flowing pressure |  |  |  |
|  | 2.1.8<br>When tested for 3 minutes as shown in Fig. 8, the device must withstand a torque of 300 in-lb while pressurized to at least 100 psi. |  |  |  |
| 3.4 and 4.4<br>The effective airway must be equal to or greater than the effective waterway through the device.<br>3.3 and 4.3<br>Air port shields must extend to the bottom of the lowest air port opening and clearance of 3/16" between shield and body must be maintained. |  |  |  |  |
|  | 2.1.2<br>Must not produce objectionable noises at any flow rate up to maximum capacity, at any pressure up to its rated maximum maintained at the inlet. | 2.1<br>Must not produce objectionable noises at any flow rate up to maximum capacity, at any pressure up to its rated maximum maintained at the inlet. |  |  |

## 10.7 Units of Measure and S. I. Conversion Factors

In NBS Document LC 1056, revised August 1975, guidelines were established to reaffirm and strengthen the commitment of NBS to the greatest practicable use of the International System of Units (S. I.) in all of its publications and also in all of its dealings with the science and engineering communities and with the public. In this report the measurements are those of the U. S. Customary units as they appear in the referenced standards, in order that the readers may give full attention to discussions and the compilation of data in this state-of-the-art report on backflow preventers. Notwithstanding the immediate objectives of this report, subsequent actions leading to the updating of backflow preventer standards should establish the metric system to the fullest extent possible.

The following conversion factors are appropriate for the units of measure that appear in this report:

Length -
1 inch (in ) = 0.0254 meter (m)
1 foot (ft ) = 0.3048 meter (m)

Mass -
1 pound-mass (lbm) = .4535924 kilogram

Temperature -
1 Degree Fahrenheit (°F) = $(1.8)^{-1}$ kelvin (K) or (°K)
Temperature Fahrenheit (°F) = (459.67 + temp. °F)/1.8 kelvins (K)

Time -
1 hour (h) = 60 minutes (min) = 3600 seconds (s)

Velocity -
1 foot per second (fps) = 0.3048 meter per second (m/s)

Force -
1 pound-force (lbf) = 4.448222 newtons (N)

Pressure -
1 pound-force per square inch (psi) = 6894.757 pascals (Pa)
6.894757 kilopascals (kPa)
1 inch of water column at 60°F = 248.84 pascals (Pa)

Volume -
1 U.S. liquid gallon (gal) = 0.003785412 meter$^3$ (m$^3$)
= 3.785412 liters (l)

Flow Rate -
1 U.S. gallon per minute (gpm) = 0.0000630902 meters$^3$/second
= 63.0902 centimeters$^3$/second (cm$^3$/s)
= 0.0630902 liters/second (l/s)